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ADVANCED COMPOSITE ELEVATOR FOR BOEING 727 AIRCRAFT

22 AUGUST 1978

FIFTH QUARTERLY TECHNICAL PROGRESS REPORT
23 MAY 1978 THROUGH 22 AUGUST 1978

PREPARED FOR:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

IN RESPONSE TO:

CONTRACT NAS1-14952
DRL LINE ITEM NUMBER 018

BOEING COMMERCIAL AIRPLANE COMPANY
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Boeing Commercial
Airplane Company
Contract NAS1-14952

This Report is Submitted in Compliance
With DRL Line Item Number 018

FIFTH QUARTERLY TECHNICAL PROGRESS REPORT
23 May through 22 August 1978

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Boeing Commercial
Airplane Company
Contract NAS1-14952

FOREWORD

This report was prepared by the Boeing Commercial Airplane Company, Renton, Washington, under Contract NAS1-14952. It is the fifth quarterly technical progress report covering work performed between 23 May 1978 and 22 August 1978. The program is sponsored by the National Aeronautics and Space Administration, Langley Research Center (NASA-LRC). Dr. H. A. Leybold is the Project Manager for NASA-LRC.

The following Boeing personnel are principal contributors to the program during the reporting period: C. R. Zehnder, Design; R. D. Wilson, Structural Analysis; M. Garvey, Manufacturing Specialist; D. Grant, Production Manager; L. D. Pritchett, Technical Operations Coordinator; and D. B. Chovil, Business Support Manager.

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SUMMARY

Detail design activities are reported for a program to develop an advanced composites elevator for the Boeing 727 commercial transport.

Design activities include discussion and results of the ancillary test programs, sustaining efforts, weight status, manufacturing producibility studies, quality assurance development, and production status.

Engineering Design has completed the release of all scheduled production drawings, and Operations has completed the required producibility studies for the elevator. The program for the fifth quarter is progressing as scheduled.

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Contract NAS1-14952

TABLE OF CONTENTS

Boeing Commercial
Airplane Company
Contract NAS1-14952

LIST OF FIGURES AND TABLES

FIGURE		PAGE

Boeing Commercial
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Contract NAS1-14952

SECTION 1.0

INTRODUCTION

The escalation of jet-fuel prices is causing a reassessment of technology concepts and trades used in designing and building commercial airplanes. The task is to incorporate fuel-saving concepts into commercial aircraft design.

The potential weight savings and fuel reduction resulting from the extensive use of advanced composites in aircraft structure are significant. However, the lack of technical confidence and cost data has delayed their use in commercial aircraft.

Hardware programs considered in a production environment are required to establish and demonstrate the safety, operating-life characteristics, and manufacturing cost of advanced composite structures.

Boeing's approach to the problem is to obtain reliable production, technical, and cost data bases by the integration of advanced composite technology development under NASA contracts, which, when combined with company effort, will accelerate the application of composites. This approach addresses these data bases, developing realistic production costs in a commercial transport manufacturing environment. Program emphases are directed toward developing the information needed to obtain an early production commitment decision by management, and will be conducted in an environment consistent with production standards.

Preliminary development efforts, as covered in the first and second quarterly reports, were devoted to conceiving, developing, and analyzing alternate design concepts, and the preparation of a technical plan to aid in selecting and evaluating material, identifying ancillary structural development test requirements, and defining full-scale ground-test and flight-test requirements necessary to obtain FAA certification.

The program was built on precontract design activities as well as contracted design activities that consider:

- Program management and plans development
- Establishing design criteria
- Conceptual and preliminary design
- Manufacturing process development
- Material evaluation and selection
- Verification test
- Detail design
- FAA approval plan definition

This report describes work accomplished during the fifth 3-month period of the contract. Design activities include the discussion of design status, weight status, results of manufacturing producibility studies, ancillary test specimen configurations and results, and production efforts. These activities are described under the headings: Design Analysis, Ancillary Testing, Operations Development, and Production. The overall program schedule status is summarized in Figure 1-1.

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Contract NAS1-14952

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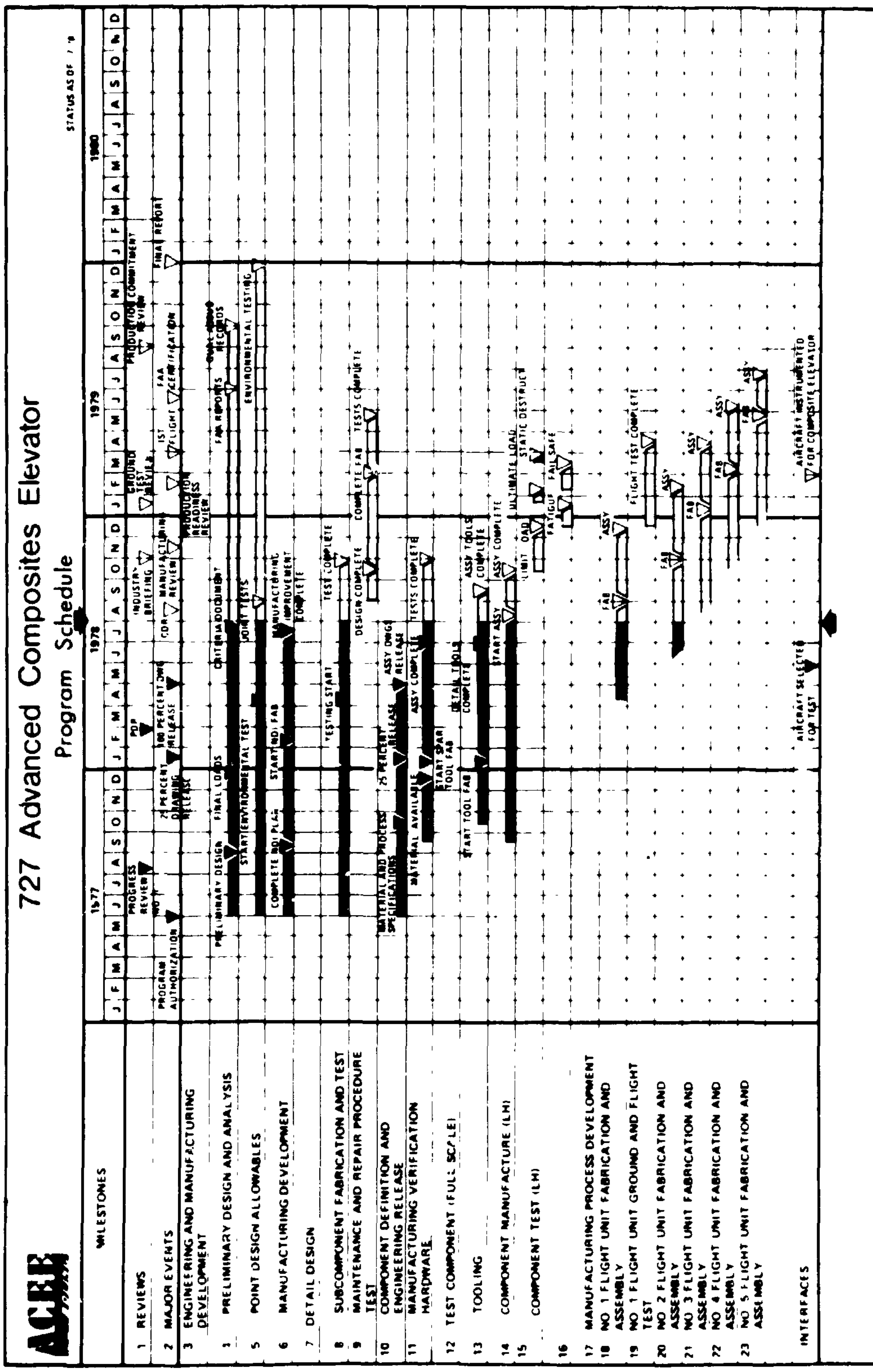

Figure 1-1. Program ... dule

SECTION 2.0

DESIGN ANALYSIS

2.1 DESIGN LOADS CRITERIA AND ANALYSIS

2.1.1 Criteria and Analysis

As part of a regular meeting schedule with the FAA, a meeting was held in May. A presentation concerning lightning strike threats, and required protection systems for the elevator, was given by the Boeing Ele odynamics staff.

Further discussions of test plans, and plans to present test results in the form of structural design values to the FAA, were included.

A presentation concerning moisture absorption in graphite/epoxy components was given to the FAA at a scheduled June meeting. The presentation discussed the mechanics of moisture absorption, and what can be expected on actual in-service components.

Work was begun in June on preparing the elevator formal stress analysis documentation.

2.2 ANCILLARY TESTING—COUPONS AND ELEMENTS

Test No. 1—Coupons—Specimen configurations and test results are shown in Figures 2-1, 2-2, and 2-3, and Tables 2-1 through 2-10.

Test No. 3—Long-Term Environmental Assessment—Specimen configurations and test results are shown in Figure 2-1, and Tables 2-7 and 2-8 (65C17706-7, -8, and -9).

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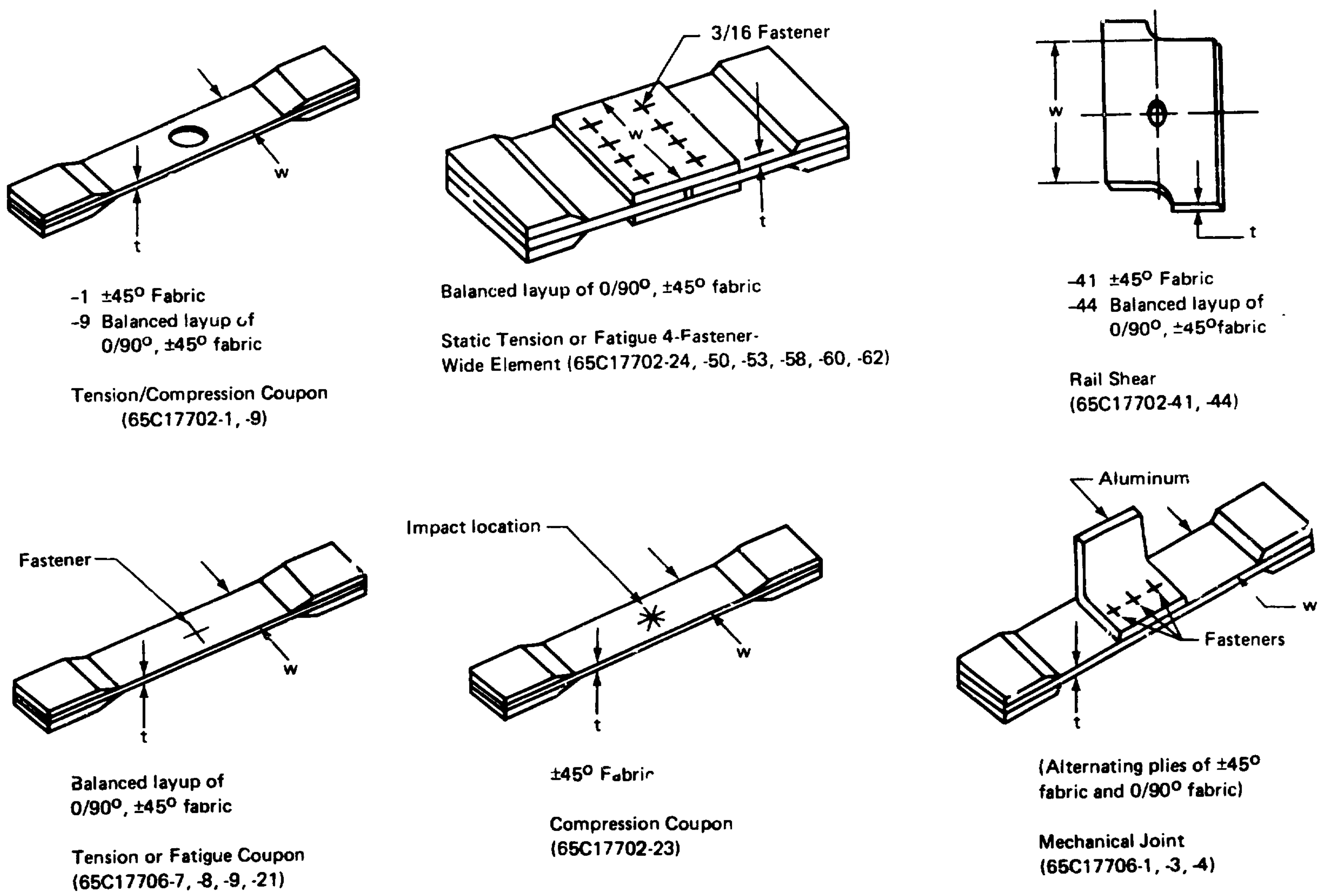

Figure 2-1. 727 Advanced Composites Elevator Ancillary Test Specimens

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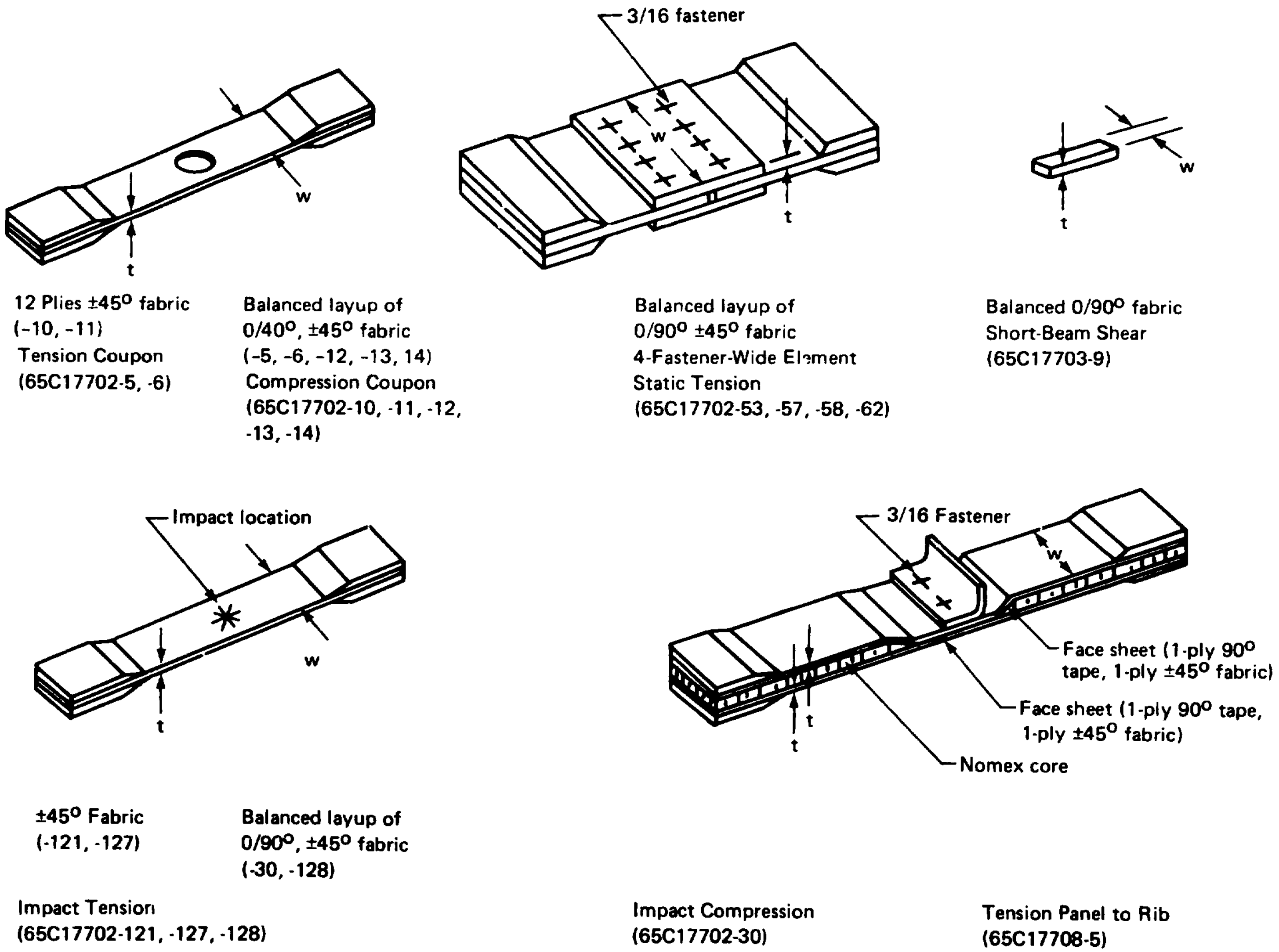
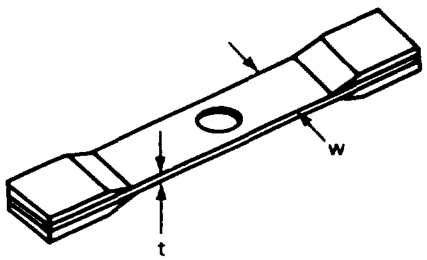
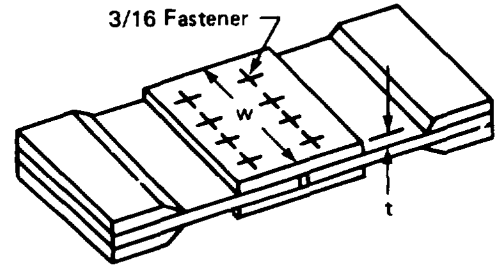


Figure 2-2. 727 Advanced Composites Elevator Ancillary Test Specimens



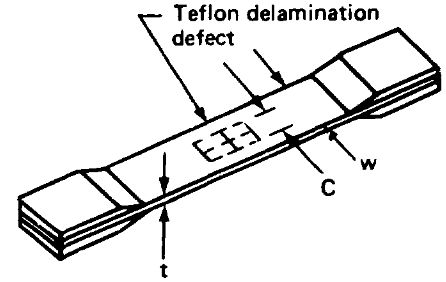
-10 ±45° Fabric
-4, -12 Balanced layup of
0/90°, ±45° fabric

Tension/Compression Coupon
(65C17702-4, -10, -12)



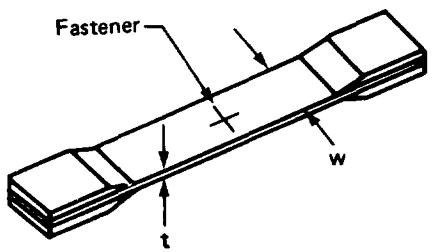
Balanced layup of 0/90°,±45° fabric

Static Tension or Fatigue 4-Fastener-
Wide Element (65C17702-60, -61, -18, -19, -51,
-63, -53, -54, -64, -56, -57)



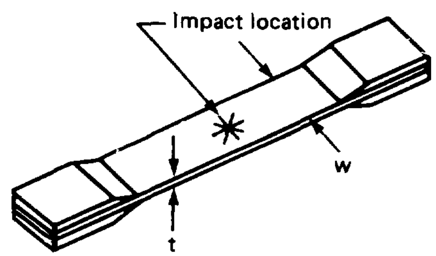
-18, -19 ±45° Fabric
-20, -21, -22 Balanced layup of
0/90°, ±45° fabric

Compression Coupon
(65C17702-18, -19, -20, -21, -22)

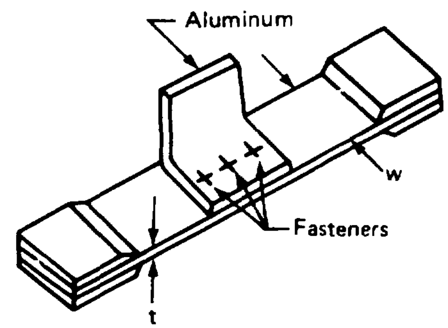


Balanced layup of
0/90°, ±45° fabric

Fatigue Coupon
(65C17706-8)



-26, -124 Balanced layup of
0/90°, ±45° fabric
-23, -29 , ±45° fabric
Compression Coupon
(65C17702-23, -29, -121, -26, -124)



(Alternating plies of ±45°
fabric and 0/90° fabric)

Mechanical Joint
(65C17706-5, -6)

Figure 2-3. 727 Advanced Composites Elevator Ancillary Test Specimens

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Table 2-1. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa			Comments
		Static	Fatigue		Dry	Wet	Impact, cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thickness		Gross	Net	Bearing	
65C17702-1	Tension coupon	X		RT		X			0 798	3.835	0 224	12.85	150.0	189.34		
65C17702-1	Tension coupon	X		RT		X			0 798	3.846	0.224	12.90	150.1	189 34		
65C17702 1	Tension coupon	X		RT		X			0 795	3.830	0 226	13.08	151 1	190.6		
65C17702 1	Tension coupon	X		-53.9		X			0 798	3.828	0 221	15.35	181.4	229 2		
65C17702 1	Tension coupon	X		-53.9		X			0 792	3.835	0 224	15.88	185.3	233.5		
65C17702-1	Tension coupon	X		-53.9		X			0 798	3.828	0 224	16.01	187.2	236 4		
65C17702-1	Tension coupon	X		71 1		X			0 798	3.823	0 226	10.79	124.8	157.8		
65C17702-1	Tension coupon	X		71.1		X			0 798	3.825	0 229	10.50	120.0	151 7		
65C17702-1	Tension coupon	X		71 1		X			0.798	3.815	0.226	10.43	120.9	152.9		
65C17702-9	Compression coupon	X		RT		X			0 792	3.820	0.231	12.92	146 4	184.6		
65C17702-9	Compression coupon	X		RT		X			0 792	3.820	0.246	12.20	129 6	163.5		
65C17702-9	Compression coupon	X		RT		X			0 792	3.820	0.234	12.76	142.9	180.3		
65C17702-9	Compression coupon	X		-53.9		X			0 792	3.820	0 234	20.46	229.2	289.2		
65C17702-9	Compression coupon	X		-53.9		X			0 792	3.820	0 229	18 77	215.0	271 2		
65C17702-9	Compression coupon	X		-53.9		X			0 787	3.807	0.231	19.24	218.6	275 6		
65C17702-9	Compression coupon	X		71 1		X			0 792	3.818	0.229	10.07	115.4	145 7		
65C17702-9	Compression coupon	X		71 1		X			0 795	3.815	0.229	10.54	120.9	152 7		
65C17702-9	Compression coupon	X		71.1		X			0 792	3.818	0.229	10.54	120.8	152.4		
65C17702-23	Compression coupon	X		RT	X		175 1			3.807	0.234	19.45	218.6			
65C17702-23	Compression coupon	X		RT	X		175 1			3.807	0.231	18.82	213.8			
65C17702-23	Compression coupon	X		RT	X		175 1			3.800	0.226	18.56	216.1			
65C17702-23	Compression coupon	X		RT	X		350 2			3.805	0.231	16.67	189.5			
65C17702-23	Compression coupon	X		RT	X		350 2			3.805	0.231	16.06	182 6			
65C17702-23	Compression coupon	X		RT	X		350.2			3.805	0.234	15.78	177.5			
65C17702-23	Compression coupon	X		RT	X		525 3			3.800	0.234	15.36	173.0			
65C17702-23	Compression coupon	X		RT	X		525.3			3.800	0.236	15.10	168.2			
65C17702-23	Compression coupon	X		RT	X		525.3			3.800	0.236	15.30	170.5			

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Table 2-2. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa				Comments
		Static	Fa-tigue		Dry	Wet	Impact cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thick-ness		Gross	Net	Bearing	Shear	
65C17702-41	Rail shear	X		RT		X			0.476	12.70	0.226	75.17	260.7				
65C17702-41	Rail shear	X		RT		X			0.476	12.70	0.229	73.66	25[illegible].2				
65C17702-41	Rail shear	X		RT		X			0.476	12.70	0.226	69.30	240.6				
65C17702-41	Rail shear	X		-53.9		X			0.476	12.70	0.229	69.83	241.6				
65C17702-41	Rail shear	X		-53.9		X			0.476	12.70	0.226	68.50	237.8				
65C17702-41	Rail shear	X		-53.9		X			0.476	12.70	0.229	71.79	248.7				
65C17702-41	Rail shear	X		71.1		X			0.476	12.70	0.229	68.50	237.1				
65C17702-41	Rail shear	X		71.1		X			0.476	12.70	0.229	76.86	266.2				
65C17702-41	Rail shear	X		71.1		X			0.476	12.70	0.229	75.44	261.0				
65C17702-44	Rail shear	X		RT		X			0.476	12.70	0.231	66.10	225.9				
65C17702-44	Rail shear	X		RT		X			0.476	12.70	0.229	65.12	224.8				
65C17702-44	Rail shear	X		RT		X			0.476	12.70	0.234	65.74	222.8				
65C17702-44	Rail shear	X		-53.9		X			0.476	12.70	0.231	62.89	214.8				
65C17702-44	Rail shear	X		-53.9		X			0.476	12.70	0.229	65.47	226.0				
65C17702-44	Rail shear	X		-53.9		X			0.476	12.70	0.234	70.55	237.7				
65C17702-44	Rail shear	X		71.1		X			0.476	12.70	0.226	59.34	206.2				
65C17702-44	Rail shear	X		71.1		X			0.476	12.70	0.229	66.28	228.0				
65C17702-44	Rail shear	X		71.1		X			0.476	12.70	0.231	63.61	217.9				

Table 2-3. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa				Comments
		Static	Fatigue		Dry	Wet	Impact cm-kN	Fastener, cm	Hole dia, cm	w-Width	t-Thickness		Gross	Net	Bearing	Shear	
65C17702-50	Element-4 fastener	X		RT		X		0.476		9.677	0.224	42.26	97.70	121 6	496.2	160.4	Shearout failure
65C17702-50	Element-4 fastener	X		RT		X		0.476		9.677	0.229	45.01	102.3	127.4	519 7	168.0	Shearout failure
65C17702-50	Element-4 fastener	X		RT		X		0.476		9.655	0.226	40.41	92.12	114.8	466.9	150.9	Shearout failure
65C17702-53	Element-4 fastener	X		RT		X		0.476		9.688	0.234	63.92	141.2	175.8	718.0	140 2	Bearing failure
65C17702-53	Element-4 fastener	X		RT		X		0.476		9.688	0.234	64.10	141.6	176.2	720.0	140.6	Bearing failure
65C17702-53	Element-4 fastener	X		RT		X		0.476		9.713	0.234	63.74	141.2	185.8	719.9	140.6	Bearing failure
65C17702-53	Element-4 fastener	X		-53.9		X		0.476		9.639	0.224	62.27	145.3	181.1	735.5	143.6	Bearing failure
65C17702-53	Element-4 fastener	X		-53.9		X		0.476		9.657	0.224	66.36	153.8	191.5	779.3	152.2	Bearing failure
65C17702-53	Element-4 fastener	X		-53.9		X		0.476		9.586	0.236	59.87	132.2	165.0	665.3	130.0	Bearing failure
65C17702-53	Element-4 fastener	X		71.1		X		0.476		9.639	0.224	53.95	125.2	136.0	633.6	123.8	Bearing failure
65C17702-53	Element-4 fastener	X		71.1		X		0.476		9 639	0.221	51.77	121.6	151.5	615.0	120.1	Bearing failure
65C17702-53	Element-4 fastener	X		71.1		X		0.476		14.70	0.229	57.74	131.2	163.6	525.1	129.5	Bearing failure
65C17702-62	Element-4 fastener	X		RT		X	350.2	0.476		9.675	0.226	50.75	116.7	145 3	592.6	113 0	Bearing failure
65C17702-62	Element-4 fastener	X		RT		X	350.2	0.476		9.672	0.229	52.40	118.5	147.6	601.7	117 5	Bearing failure
65C17702-62	Element-4 fastener	X		RT		X	350.2	0.476		9.682	0.231	55.02	123.6	153.9	628.3	122.7	Bearing failure
65C17706-21	Tension coupon	X		RT		X		0.476		3.813	0.234	20.99	235.7	282.8			
65C17706-21	Tension coupon	X		RT		X		0.476		3.815	0.241	21.84	237.3	284.6			
65C17706-21	Tension coupon	X		RT		X		0.476		3.823	0.239	21.13	231.5	277.6			

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Table 2-4. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Fatigue load				Comments
		Static	Fa-tigue		Dry	Wet	Impact cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thick-ness	R	P_{MAX}, kN	Cycles to failure	Max cycles—no failure	
65C17702-24	Element-4 fastener		X	RT	X			0.476		5.791	0.229	−1.0	±10.19		500 000	
65C17702-24	Element-4 fastener		X	RT	X			0.476		5.791	0.229	−1.0	±10.19		500 000	
65C17702-24	Element-4 fastener		X	RT	X			0.476		5.791	0.229	−1.0	±10.19		500 000	
65C17702-50	Element-4 fastener		X	RT	X			0.476		9.652	0.229	−1.0	±10.01		500 000	
65C17702-50	Element-4 fastener		X	RT	X			0.476		9.652	0.229	−1.0	±10.01		500 000	
65C17702-50	Element-4 fastener		X	RT	X			0.476		9.652	0.229	−1.0	±10.01		500 000	
65C17702-50	Element-4 fastener		X	RT		X		0.476		9.652	0.229	−1.0	±10.01		500 000	
65C17702-50	Element-4 fastener		X	RT		X		0.476		9.652	0.229	−1.0	±10.01		500 000	
65C17702-50	Element-4 fastener		X	RT		X		0.476		9.652	0.229	−1.0	±10.01		500 000	
65C17702-53	Element-4 fastener		X	RT	X			0.476		9.652	0.229	−1.0	±15.43		500 000	
65C17702-53	Element-4 fastener		X	RT	X			0.476		9.652	0.229	−1.0	±15.43		500 000	
65C17702-53	Element-4 fastener		X	RT	X			0.476		9.652	0.229	−1.0	±15.43		500 000	
65C17702-53	Element-4 fastener		X	71.1	X			0.476		9.652	0.229	−1.0	±12.94		500 000	
65C17702-53	Element-4 fastener		X	71.1	X			0.476		9.652	0.229	−1.0	±12.94		500 000	
65C17702-53	Element-4 fastener		X	71.1	X			0.476		9.652	0.229	−1.0	±12.94		500 000	
65C17702-53	Element-4 fastener		X	RT		X		0.476		9.652	0.229	−1.0	±15.43		500 000	
65C17702-53	Element-4 fastener		X	RT		X		0.476		9.652	0.229	−1.0	±15.43		500 000	
65C17702-53	Element-4 fastener		X	RT		X		0.476		9.652	0.229	−1.0	±15.43		500 000	
65C17702-53	Element-4 fastener		X	-53.9		X		0.476		9.652	0.229	−1.0	±15.17		500 000	
65C17702-53	Element-4 fastener		X	-53.9		X		0.476		9.652	0.229	−1.0	±15.17		500 000	
65C17702-53	Element-4 fastener		X	-53.9		X		0.476		9.652	0.229	−1.0	±15.17		500 000	
65C17702-53	Element-4 fastener		X	71.1		X		0.476		9.652	0.229	−1.0	±12.94		500 000	
65C17702-53	Element-4 fastener		X	71.1		X		0.476		9.652	0.229	−1.0	±12.94		500 000	
65C17702-53	Element-4 fastener		X	71.1		X		0.476		9.652	0.229	−1.0	±12.94		500 000	
65C17702-58	Element-4 fastener		X	RT	X			0.476		9.652	0.152	−1.0	± 9.741		500 000	
65C17702-58	Element-4 fastener		X	RT	X			0.476		9.652	0.152	−1.0	± 9.741		500 000	
65C17702-58	Element-4 fastener		X	RT	X			0.476		9.652	0.152	−1.0	± 9.741		500 000	

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Table 2-5. Test Results

Part number	Description	Test type: Static	Test type: Fatigue	Test temp, °C	Environmental condition: Dry	Environmental condition: Wet	Specimen detail: Impact cm-kN	Specimen detail: Fastener, cm	Specimen detail: Hole dia, cm	Specimen size, cm: -w- Width	Specimen size, cm: -t- Thickness	Fatigue load: R	Fatigue load: P_{MAX}, kN	Fatigue load: Cycles to failure	Fatigue load: Max cycles—no failure	Comments
65C17706-8	Coupon		X	RT	X			0.476		3.810	0.229	−1.0	±4.782		500 000	Specimen damaged prior to test—under investigation
65C17706-8	Coupon		X	RT	X			0.476		3.810	0.229	−1.0	±4.782			
65C17706-8	Coupon		X	RT	X			0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	71.1	X			0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	71.1	X			0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	71.1	X			0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	RT		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	RT		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	RT		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	-53.9		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	-53.9		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	-53.9		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	71.1		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	71.1		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-8	Coupon		X	71.1		X		0.476		3.810	0.229	−1.0	±4.782		500 000	
65C17706-9	Coupon		X	RT	X			0.476		3.810	0.229	−1.0	±4.670		500 000	
65C17706-9	Coupon		X	RT	X			0.476		3.810	0.229	−1.0	±4.670		500 000	
65C17706-9	Coupon		X	RT	X			0.476		3.810	0.229	−1.0	±4.670		500 000	

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Table 2-6. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa			Comments
		Static	Fa-tigue		Dry	Wet	Impact, cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thick-ness		Gross	Net	Bearing	
65C17702-121	Tension coupon	X		RT	X		175.1			3.818	0.231	16.59	187.8			
65C17702-121	Tension coupon	X		RT	X		175.1			3.813	0.229	16.32	187.1			
65C17702-121	Tension coupon	X		RT	X		175.1			3.813	0.231	16.95	192.1			
65C17702-121	Tension coupon	X		RT	X		350.2			3.820	0.231	15.66	177.3			
65C17702-121	Tension coupon	X		RT	X		350.2			3.810	0.229	15.57	177.4			
65C17702-121	Tension coupon	X		RT	X		350.2			3.823	0.229	15.79	180.7			
65C17702-121	Tension coupon	X		RT	X		525.3			3.820	0.231	14.37	162.7			
65C17702-121	Tension coupon	X		RT	X		525.3			3.815	0.231	14.86	168.2			
65C17702-121	Tesnion coupon	X		RT	X		525.3			3.820	0.231	14.86	168.0			
65C17702-127	Tension coupon	X		RT	X		262.65			3.797	0.165	9.919	54.8			
65C17702-127	Tension coupon	X		RT	X		262.65			3.785	0.173	10.19	155.8			
65C17702-127	Tension coupon	X		RT	X		262.65			3.797	0.178	10.23	151.6			
65C17702-128	Tension coupon	X		RT	X		262.65			3.823	0.160	15.48	252.7			
65C17702-128	Tension coupon	X		RT	X		262.65			3.820	0.160	15.57	255.0			
65C17702-128	Tension coupon	X		RT	X		262.65			3.818	0.160	15.57	255.0			
65C17702-53	Element-4 fastener	X		-53.9	X			0.476		9.667	0.224	61.29	141.8	176.6	719.8	Bearing failure
65C17702-53	Element-4 fastener	X		-53.9	X			0.476		9.662	0.231	57.96	130.5	162.5	661.9	Bearing failure
65C17702-53	Element-4 fastener	X		-53.9	X			0.476		9.660	0.226	62.94	144.9	180.6	734.9	Bearing failure
65C17702-53	Element-4 fastener	X		71.1	X			0.476		9.660	0.224	52.26	121.8	151.6	617.2	Bearing failure
65C17702-53	Element-4 fastener	X		71.1	X			0.476		9.660	0.224	51.20	118.6	147.7	601.2	Bearing failure
65C17702-57	Element-4 fastener	X		RT	X			0.476		13.454	0.229	63.16	102.7	119.6	725.3	Bearing failure
65C17702-57	Element-4 fastener	X		RT	X			0.476		13.454	0.226	61.12	100.5	117.1	709.6	Bearing failure
65C17702-57	Element-4 fastener	X		RT	X			0.476		13.490	0.231	66.59	107.4	125.0	760.4	Bearing failure
65C17702-58	Element-4 fastener	X		RT	X			0.476		9.655	0.152	38.28	130.1	162.0	659.2	Bearing failure
65C17702-58	Element-4 fastener	X		RT	X			0.476		9.655	0.152	40.30	136.9	170.7	694.1	Bearing failure
65C17702-58	Element-4 fastener	X		RT	X			0.476		9.655	0.155	38.12	128.5	160.0	651.2	Bearing failure

Table 2-7. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa			Comments
		Static	Fatigue		Dry	Wet	Impact, cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thickness		Gross	Net	Bearing	
65C17702-62	Element-4 fastener	X		RT	X		350 2	0 476		9 665	0 229	51 11	116 3	144 9	590 1	Bearing failure
65C17702-62	Element-4 fastener	X		RT	X		350 2	0 476		9 670	0 229	48.57	109.9	136 9	557 7	Bearing failure
65C17702-62	Element-4 fastener	X		RT	X		350 2	0 476		0 657	0 229	53.38	120.9	150 6	612.8	Bearing failure
65C17703-9	Short-beam shear	X		RT	X					0 643	0 229	1.383	70 55			Shear failure
65C17703-9	Short-beam shear	X		RT	X					0 645	0 229	1.486	75 50			Shear failure
65C17703-9	Short-beam shear	X		RT	X					0 644	0 229	1 308	66 61			Shear failure
65C17703-9	Short-beam shear	X		RT	X					0 641	0 229	1.303	66 67			Shear failure
65C17703-9	Short-beam shear	X		RT	X					0 644	0 229	1 125	57 37			Shear failure
65C17708-5	Tension, panel-to-rib	X		RT	X			0 476		6.35	0 028	5.249	147.9*			
65C17708-5	Tension, panel-to-rib	X		RT	X			0 476		6 35	0 028	5.471	154 2*			
65C17708-5	Tension, panel-to-rib	X		RT	X			0 476		6 35	0.028	7.784	219.4*			
65C17708-5	Tension, panel-to-rib	X		RT	X			0 476		6 35	0 028	4.136	116.6*			
65C17708-5	Tension, panel-to-rib	X		RT	X			0 476		6 35	0 028	6.850	193 1*			

$* \sigma = \frac{\text{FAILURE LOAD}}{2tw}$

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Table 2-8. Test Results

Part number	Description	Test type: Static	Test type: Fatigue	Test temp, °C	Environmental condition: Dry	Environmental condition: Wet	Specimen detail: Impact, cm-kN	Specimen detail: Fastener, cm	Specimen detail: Hole dia, cm	Specimen size, cm: -w- Width	Specimen size, cm: -t- Thickness	Failure load, kN	Failure stress, MPa: Gross	Failure stress, MPa: Net	Failure stress, MPa: Bearing	Comments
65C17702-5	Tension coupon	X		RT	X				0.246	3.802	0.246	28.82	307.7	329.0		
65C17702-5	Tension coupon	X		RT	X				0.246	3.797	0.246	25.35	271.0	289.8		
65C17702-5	Tension coupon	X		RT	X				0.246	3.797	0.244	26.07	281.5	301.0		
65C17702-6	Tension coupon	X		RT	X				1.270	3.802	0.246	14.23	152.2	228.2		
65C17702-6	Tension coupon	X		RT	X				1.270	3.810	0.246	14.46	154.0	231.1		
65C17702-6	Tension coupon	X		RT	X				1.270	3.802	0.241	14.90	162.4	243.9		
65C17702-10	Compression coupon	X		RT	X				0.254	3.856	0.226	19.35	221.7	236.4		
65C17702-10	Compression coupon	X		RT	X				0.254	3.830	0.226	19.26	222.2	236.9		
65C17702-11	Compression coupon	X		RT	X				1.270	3.807	0.229	11.25	120.3	194.0		
65C17702-11	Compression coupon	X		RT	X				1.270	3.815	0.229	12.05	138.5	206.0		
65C17702-11	Compression coupon	X		RT	X				1.270	3.744	0.229	10.54	121.8	183.0		
65C17702-12	Compression coupon	X		RT	X				0.795	3.818	0.236	23.93	265.5	335.4		
65C17702-12	Compression coupon	X		RT	X				0.795	3.818	0.234	21.66	242.9	306.8		
65C17702-12	Compression coupon	X		RT	X				0.795	3.818	0.236	24.64	273.2	345.2		
65C17702-13	Compression coupon	X		RT	X				0.249	3.820	0.231	28.78	325.9	348.7		
65C17702-13	Compression coupon	X		RT	X				0.246	3.813	0.239	31.14	342.1	365.7		
65C17702-13	Compression coupon	X		RT	X				0.241	3.813	0.234	30.74	345.0	368.3		
65C17702-14	Compression coupon	X		RT	X				1.278	3.823	0.234	17.48	195.6	293.8		
65C17702-14	Compression coupon	X		RT	X				1.270	3.823	0.239	16.81	184.4	276.2		
65C17702-14	Compression coupon	X		RT	X				1.270	3.825	0.239	16.81	183.9	275.2		
65C17702-30	Compression coupon	X		RT	X		525.3			3.810	0.165	11.30	179.6			
65C17702-30	Compression coupon	X		RT	X		525.3			3.810	0.165	12.37	196.6			
65C17702-30	Compression coupon	X		RT	X		525.3			3.810	0.165	12.23	194.5			

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Table 2-9. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa			Comments
		Static	Fatigue		Dry	Wet	Impact cm-kN	Fastener, cm	Delam, cm	w Width	t Thickness		Gross	Net	Bearing	
65C17702-18	Compression coupon	X		RT	X				0.762	3.815	0.229	15.39	176.5			
65C17702-18	Compression coupon	X		RT	X				0.762	3.813	0.246	19.35	206.0			
65C17702-18	Compression coupon	X		RT	X				0.762	3.810	0.249	18.95	199.8			
65C17702-19	Compression coupon	X		RT	X				1.27	3.810	0.251	18.46	192.9			
65C17702-19	Compression coupon	X		RT	X				1.27	3.815	0.249	18.95	199.5			
65C17702-19	Compression coupon	X		RT	X				1.27	3.815	0.257	19.44	198.6			
65C17702-20	Compression coupon	X		RT	X				0.254	3.820	0.236	33.45	370.7			
65C17702-20	Compression coupon	X		RT	X				0.254	3.818	0.234	34.25	384.0			
65C17702-20	Compression coupon	X		RT	X				0.254	3.820	0.234	32.83	367.8			
65C17702-21	Compression coupon	X		RT	X				0.762	3.820	0.244	32.47	348.6			
65C17702-21	Compression coupon	X		RT	X				0.762	3.818	0.239	34.03	373.4			
65C17702-22	Compression coupon	X		RT	X				1.27	3.813	0.234	30.91	347.0			
65C17702-22	Compression coupon	X		RT	X				1.27	3.813	0.234	35.90	402.9			
65C17702-22	Compression coupon	X		RT	X				1.27	3.810	0.234	34.25	384.7			
65C17702-23	Compression coupon	X		RT		X	525.3			3.800	0.234	13.52	152.3			
65C17702-23	Compression coupon	X		RT		X	525.3			3.800	0.234	13.61	153.3			
65C17702-23	Compression coupon	X		RT		X	525.3			3.805	0.234	13.03	146.6			
65C17702-26	Compression coupon	X		RT	X		175.1			3.802	0.254	24.24	251.0			
65C17702-26	Compression coupon	X		RT	X		175.1			3.805	0.246	24.95	266.2			
65C17702-26	Compression coupon	X		RT	X		175.1			3.815	0.251	24.86	259.2			
65C17702-26	Compression coupon	X		RT	X		350.2			3.807	0.249	18.73	194.2			
65C17702-26	Compression coupon	X		RT	X		350.2			3.807	0.249	19.62	211.3			
65C17702-26	Compression coupon	X		RT	X		350.2			3.807	0.244	19.84	213.7			
65C17702-26	Compression coupon	X		RT	X		525.3			3.802	0.246	16.01	180.4			
65C17702-26	Compression coupon	X		RT	X		525.3			3.807	0.254	17.70	183.1			
65C17702-26	Compression coupon	X		RT	X		525.3			3.805	0.244	18.01	194.2			

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Table 2-10. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa			Comments
		Static	Fatigue		Dry	Wet	Impact, cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thickness		Gross	Net	Bearing	
65C17702-4	Tension coupon	X		RT	X				0.7925	3.813	0.249	20.02	210.9	266.3		
65C17702-4	Tension coupon	X		RT	X				0.7925	3.810	0.251	19.26	201.1	253.9		
65C17702-4	Tension coupon	X		RT	X				0.7925	3.797	0.251	18.63	195.1	246.6		
65C17702-4	Tension coupon	X		RT		X			0.7925	3.810	0.239	18.90	207.7	262.3		
65C17702-4	Tension coupon	X		RT		X			0.7925	3.813	0.239	20.32	212.1	269.5		
65C17702-4	Tension coupon	X		RT		X			0.7925	3.813	0.239	19.06	209.3	264.3		
65C17702-4	Tension coupon	X		-53.9	X				0.7925	3.805	0.244	16.60	178.9	226.0		
65C17702-4	Tension coupon	X		-53.9	X				0.7925	3.807	0.251	16.73	174.8	220.7		
65C17702-4	Tension coupon	X		-53.9	X				0.7925	3.805	0.254	17.75	183.7	231.9		
65C17702-4	Tension coupon	X		-53.9		X			0.7925	3.815	0.241	18.20	193.6	249.6		
65C17702-4	Tension coupon	X		-53.9		X			0.7925	3.820	0.239	17.72	190.7	240.4		
65C17702-4	Tension coupon	X		-53.9		X			0.7925	3.813	0.236	16.87	187.3	236.4		
65C17702-4	Tension coupon	X		71.1	X				0.7925	3.805	0.246	18.54	197.8	249.9		
65C17702-4	Tension coupon	X		71.1	X				0.7925	3.805	0.249	18.83	198.8	251.1		
65C17702-4	Tension coupon	X		71.1	X				0.7925	3.805	0.249	19.47	205.6	259.7		
65C17702-4	Tension coupon	X		71.1		X			0.7925	3.805	0.236	19.42	216.1	272.9		
65C17702-4	Tension coupon	X		71.1		X			0.7925	3.810	0.239	17.93	197.1	248.8		
65C17702-4	Tension coupon	X		71.1		X			0.7925	3.818	0.234	19.95	197.1	280.9		
65C17702-10	Compression coupon	X		RT	X				0.249	3.813	0.226	18.50	214.7	229.7		
65C17702-12	Compression coupon	X		RT		X			0.795	3.820	0.236	21.35	236.6	298.8		
65C17702-12	Compression coupon	X		RT		X			0.795	3.820	0.234	20.46	268.1	289.5		
65C17702-12	Compression coupon	X		RT		X			0.795	3.823	0.241	21.17	229.5	289.8		
65C17702-12	Compression coupon	X		-53.9	X				0.795	3.813	0.251	28.29	295.1	372.9		
65C17702-12	Compression coupon	X		-53.9	X				0.795	3.813	0.246	23.86	251.9	318.3		
65C17702-12	Compression coupon	X		-53.9	X				0.795	3.815	0.234	23.84	267.5	337.9		
65C17702-12	Compression coupon	X		71.1	X				0.795	3.823	0.239	16.41	179.8	221.5		
65C17702-12	Compression coupon	X		71.1	X				0.795	3.820	0.241	18.46	200.3	252.9		
65C17702-12	Compression coupon	X		71.1	X				0.795	3.820	0.234	19.75	221.3	278.4		
65C17702-12	Compression coupon	X		71.1		X			0.795	3.815	0.246	21.53	229.1	289.4		
65C17702-12	Compression coupon	X		71.1		X			0.795	3.815	0.249	21.62	227.7	287.6		
65C17702-12	Compression coupon	X		71.1		X			0.795	3.813	0.246	22.73	242.0	305.7		

Test No. 4—Elements (Fastened Joints)—Specimen configurations and test results are shown in Figure 2-1 and Tables 2-2, 2-3, 2-4, 2-11, 2-12, 2-13, and 2-14. Repeated load test specimens are cycled to 500,000 cycles at R= -1.0 at 10 Hz. The fully reversed test load used is approximately 25% of the static ultimate strength of the laminate. The 500,000 cycles are representative of service requirements for the 727 elevator.

Test No. 8—Panel/Rib Pad—Figure 2-4 shows the test setup for this test. Elevator skin panel support at rib intersections was simulated for this test. Specimens were tension tested to failure, using a hydraulic grip machine setup. Test results are presented in Table 2-7.

Test No. 9—Spar/Shear Web—Figure 2-5 shows the setup for the first spar/shear web picture frame test, conducted in April 1978. Back-to-back strain gage rosettes were installed on the six-ply ($\pm$ 45° orientation fabric) web between stiffeners.

A maximum principal shear strain of 0.0050, and a maximum normal strain of 0.0041, was obtained at the strain gage locations in the buckled web prior to panel failure. The panel web failure was at a web-stiffener attach fastener hole.

The shear flow in the web at time of failure was 164 N/m, which is approximately 3-1/2 times the critical design shear load in the front spar web.

A summary of the panel failure loads, stresses, and strains is presented in Table 2-15. Detailed strain gage results for each panel are shown in Tables 2-16, 2-17, and 2-18. As can be seen, the failure load values for three panels are very close to one another.

Table 2-11. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Fatigue load				Comments
		Static	Fatigue		Dry	Wet	Impact cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thickness	R	P_{MAX}, kN	Cycles to failure	Max cycles—no failure	
65C17706-5	Mechanical joint		X	RT	X			0.476	Teflon defect	2.54	0.229	±1.0	3.02		500 000	
65C17706-5	Mechanical joint		X	RT	X			0.476	Teflon defect	2.54	0.229	±1.0	3.02		500 000	
65C17706-5	Mechanical joint		X	RT	X			0.476	Teflon defect	2.54	0.229	±1.0	3.02		500 000	
65C17706-6	Mechanical joint		X	RT	X			0.476	Teflon defect	2.54	0.229	±1.0	3.20		500 000	
65C17706-6	Mechanical joint		X	RT	X			0.476	Teflon defect	2.54	0.229	±1.0	3.20		500 000	
65C17706-6	Mechanical joint		X	RT	X			0.476	Teflon defect	2.54	0.229	±1.0	3.20		500 000	
65C17706-8	Filled hole		X	-53.9	X			0.476		2.54	0.229	±1.0	4.80		500 000	
65C17706-8	Filled hole		X	-53.9	X			0.476		2.54	0.229	±1.0	4.80		500 000	
65C17706-8	Filled hole		X	-53.9	X			0.476		2.54	0.229	±1.0	4.80		500 000	

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Table 2-12. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Fatigue load				Comments
		Static	Fatigue		Dry	Wet	Impact cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thickness	R	P_{MAX}, kN	Cycles to failure	Max cycles—no failure	
65C17702-51	Element-4 fastener		X	RT	X			0.476		13.51	0.229	±1.0	9.56		500 000	
65C17702-51	Element-4 fastener		X	RT	X			0.476		13.51	0.229	±1.0	9.56		500 000	
65C17702-51	Element-4 fastener		X	RT	X			0.476		13.51	0.231	±1.0	9.56		500 000	
65C17702-63	Element-4 fastener		X	RT	X			0.476		5.79	0.226	±1.0	11.56		500 000	
65C17702-63	Element-4 fastener		X	RT	X			0.476		5.79	0.226	±1.0	11.56		500 000	
65C17702-63	Element-4 fastener		X	RT	X			0.476		5.79	0.226	±1.0	11.56		500 000	
65C17702-53	Element-4 fastener		X	RT	X			0.476		9.65	0.229	±1.0	15.43		500 000	
65C17702-53	Element-4 fastener		X	RT	X			0.476		9.65	0.229	±1.0	15.43		500 000	
65C17702-53	Element-4 fastener		X	RT	X			0.476		9.65	0.229	±1.0	15.43		500 000	
65C17702-54	Element-4 fastener		X	RT	X			0.476		13.51	0.229	±1.0	14.46		500 000	
65C17702-54	Element-4 fastener		X	RT	X			0.476		13.51	0.229	±1.0	14.46		500 000	
65C17702-54	Element-4 fastener		X	RT	X			0.476		13.51	0.229	±1.0	14.46		500 000	
65C17702-64	Element-4 fastener		X	RT	X			0.476		5.79	0.224	±1.0	11.74		500 000	
65C17702-64	Element-4 fastener		X	RT	X			0.476		5.79	0.224	±1.0	11.74		500 000	
65C17702-64	Element-4 fastener		X	RT	X			0.476		5.79	0.224	±1.0	11.74		500 000	
65C17702-56	Element-4 fastener		X	RT	X			0.476		9.65	0.229	±1.0	14.95		500 000	
65C17702-56	Element-4 fastener		X	RT	X			0.476		9.65	0.229	±1.0	14.95		500 000	
65C17702-56	Element-4 fastener		X	RT	X			0.476		9.65	0.229	±1.0	14.95		500 000	
65C17702-57	Element-4 fastener		X	RT	X			0.476		13.46	0.229	±1.0	15.92		500 000	
65C17702-57	Element-4 fastener		X	RT	X			0.476		13.46	0.229	±1.0	15.92		500 000	
65C17702-57	Element-4 fastener		X	RT	X			0.476		13.46	0.229	±1.0	15.92		500 000	
65C17702-61	Element-4 fastener		X	RT	X			0.476	Teflon defect	9.65	0.229	±1.0	11.74		500 000	
65C17702-61	Element-4 fastener		X	RT	X			0.476	Teflon defect	9.65	0.229	±1.0	11.74		500 000	
65C17702-61	Element-4 fastener		X	RT	X			0.476	Teflon defect	9.65	0.229	±1.0	11.74		500 000	

Table 2-13. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Failure load, kN	Failure stress, MPa				Comments
		Static	Fatigue		Dry	Wet	Impact cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thickness		Gross	Net	Bearing	Shear	
65C17702-29	Compression coupon	X		RT	X		262 7			3.815	0 157	10.50	174 7				
65C17702-29	Compression coupon	X		RT	X		262 7			3.813	0 157	9 74	162 2				
65C17702-29	Compression coupon	X		RT	X		262 7			3.810	0 165	9.07	144.2				
65C17702 121	Tension coupon	X		RT		X	525 3			3.815	0.231	13.48	152.9				
65C17702-121	Tension coupon	X		RT		X	525 3			3.818	0.231	14 17	160 6				
65C17702-121	Tension coupon	X		RT		X	525 3			3.820	0.231	14.11	163 2				
65C17702-124	Tension coupon	X		RT	X		175 1			3.810	0.254	37 63	388 9				
65C17702-124	Tension coupon	X		RT	X		175 1			3.810	0 254	35 23	364 1				
65C17702-124	Tension coupon	X		RT	X		175 1			3.810	0 254	37.67	389 4				
65C17702-124	Tension coupon	X		RT	X		350 2			3.810	0.254	28 40	293 5				
65C17702-124	Tension coupon	X		RT	X		350 2			3.810	0.254	28.02	289.6				
65C17702-124	Tension coupon	X		RT	X		350 2			3.810	0.254	33.04	341 4				
65C17702 124	Tension coupon	X		RT	X		525 3			3.810	0 254	21 88	226 2				
65C17702 124	Tension coupon	X		RT	X		525.3			3.810	0 254	23 53	243.2				
65C17702-124	Tension coupon	X		RT	X		525 3			3 810	0.254	25.93	268.0				
65C17702-60	Element-4 fastener	X		RT		X		0.476		9 657	0.312	80 73	133.8	166.7	678 3	132.5	Bearing failure
65C17702-60	Element-4 fastener	X		RT		X		0 476		9.657	0 310	80 73	134.9	169 4	683.8	133 6	Bearing failure
65C17702-60	Element-4 fastener	X		RT		X		0 476		9 634	0 307	82.33	139.6	174.0	706 1	137.9	Bearing failure
65C17702-61	Element-4 fastener	X		RT	X			0 476	Teflon defect	9.657	0 231	63.92	144.0	179 3	729.9	142 6	Bearing failure
65C17702 61	Element-4 fastener	X		RT	X			0.476	Teflon defect	9 655	0 231	63 92	144.0	179 3	729.9	142.6	Bearing failure
65C17706-18	Tension mechanical joint	X		RT	X			Csk 0 476	Teflon defect	2.535	0.229	12.86	220.0	273.5			
65C17706-18	Tension mechanical joint	X		RT	X			Csk 0.476	Teflon defect	2.537	0.231	12.30	209.8	253 3			
65C17706-18	Tension mechanical joint	X		RT	X			Csk 0.476	Teflon defect	2.537	0.234	12.81	216.1	286 0			
65C17706-19	Tension mechanical joint	X		RT	X			Non csk 0.476	Teflon defect	2.540	0.246	14.65	234.2	286.8			
65C17706-19	Tension mechanical joint	X		RT	X			Non csk 0 476	Teflon defect	2.535	0.254	13.08	203.1	250.1			
65C17706-19	Tension mechanical joint	X		RT	X			Non csk 0.476	Teflon defect	2.535	0.249	14.14	224.2	276.1			

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Table 2-14. Test Results

Part number	Description	Test type		Test temp, °C	Environmental condition		Specimen detail			Specimen size, cm		Fatigue load				Comments
		Static	Fa-tigue		Dry	Wet	Impact cm-kN	Fastener, cm	Hole dia, cm	-w- Width	-t- Thick-ness	R	P_{MAX}, kN	Cycles to failure	Max cycles — no failure	
65C17702-60	Element-4 fastener		X	RT	X			0.476		9.652	0.305	−1.0	±20.02		500 000	
65C17702-60	Element-4 fastener		X	RT	X			0.476		9.652	0.305	−1.0	±20.02		500 000	
65C17702-60	Element-4 fastener		X	RT	X			0.476		9.652	0.305	−1.0	±20.02	214 070		Fastener failure
65C17708-62	Element-4 fastener		X	RT	X		350.2	0.476		9.652	0.229	−1.0	±12.77		500 000	
65C17708-62	Element-4 fastener		X	RT	X		350.2	0.476		9.652	0.229	−1.0	±12.77		500 000	
65C17708-62	Element-4 fastener		X	RT	X		350.2	0.476		9.652	0.229	−1.0	±12.77		500 000	
65C17708-62	Element-4 fastener		X	RT		X	350.2	0.476		9.652	0.229	−1.0	±12.77		500 000	
65C17708-62	Element-4 fastener		X	RT		X	350.2	0.476		9.652	0.229	−1.0	±12.77		500 000	
65C17708-62	Element-4 fastener		X	RT		X	350.2	0.476		9.652	0.229	−1.0	±12.77		500 000	
65C17706-1	Mechanical joint		X	RT	X			Csk 0.476		2.54	0.165	−1.0	± 4.45		500 000	
65C17706-1	Mechanical joint		X	RT	X			Csk 0.476		2.54	0.165	−1.0	± 4.45		500 000	
65C17706-1	Mechanical joint		X	RT	X			Csk 0.476		2.54	0.165	−1.0	± 4.45		500 000	
65C17706-3	Mechanical joint		X	RT	X			Csk 0.476		2.54	0.229	−1.0	± 3.00		500 000	
65C17706-3	Mechanical joint		X	RT	X			Csk 0.476		2.54	0.229	−1.0	± 3.00	0		Specimen crushed by hydraulic grips
65C17706-3	Mechanical joint		X	RT	X			Csk 0.476		2.54	0.229	−1.0	± 3.00		500 000	
65C17706-4	Mechanical joint		X	RT	X			Non csk 0.476		2.54	0.229	−1.0	± 3.11		500 000	
65C17706-4	Mechanical joint		X	RT	X			Non csk 0.476		2.54	0.229	−1.0	± 3.11		500 000	
65C17706-4	Mechanical joint		X	RT	X			Non csk 0.476		2.54	0.229	−1.0	± 3.11		867 450	
65C17706-7	Coupon		X	RT	X			0.476		3.81	0.229	−1.0	± 5.38		500 000	
65C17706-7	Coupon		X	RT	X			0.476		3.81	0.229	−1.0	± 5.38		500 000	
65C17706-7	Coupon		X	RT	X			0.476		3.81	0.229	−1.0	± 5.38		500 000	

Figure 2-4. Cover Panel Padup at Ribs Static Test

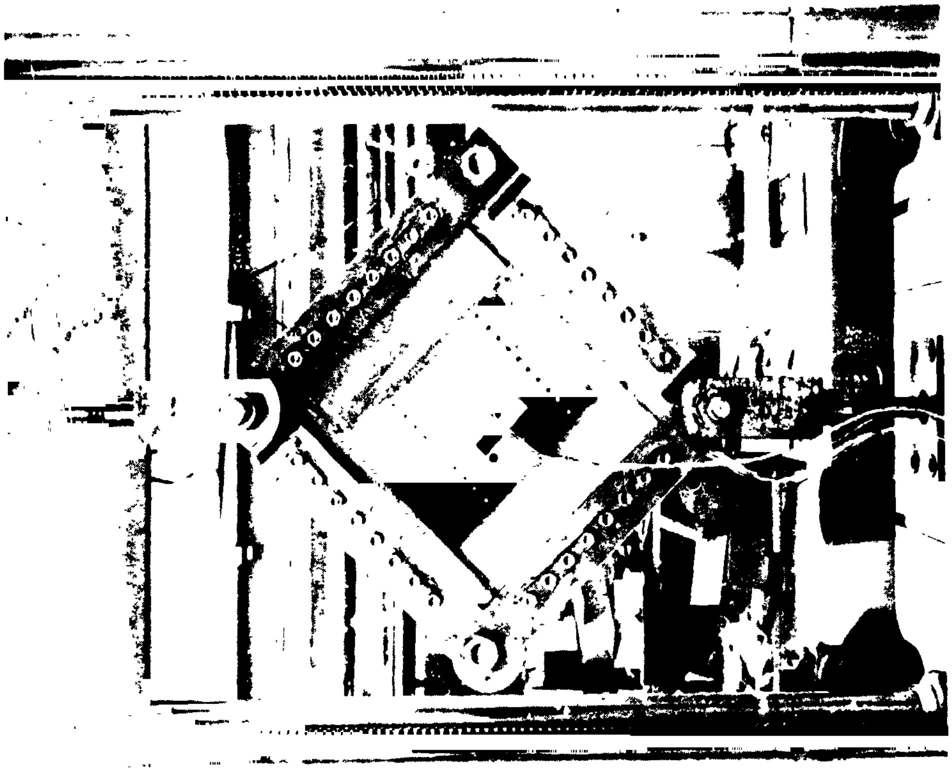

Figure 2-5. Inplane Shear Test Front Spar Shear Web

Table 2-15. Spar Web Shear Test—Summary

Test panel no.	Maximum load, P	Maximum shear stress	Maximum normal strain	Maximum shear strain
1	147 kN	-143.4	0.0041	0.0050
2	154 kN	-152.0	0.0044	0.0053
3	150 kN	-144.2	0.0043	0.0050
Average		-146.5 $\frac{MN}{m^2}$		

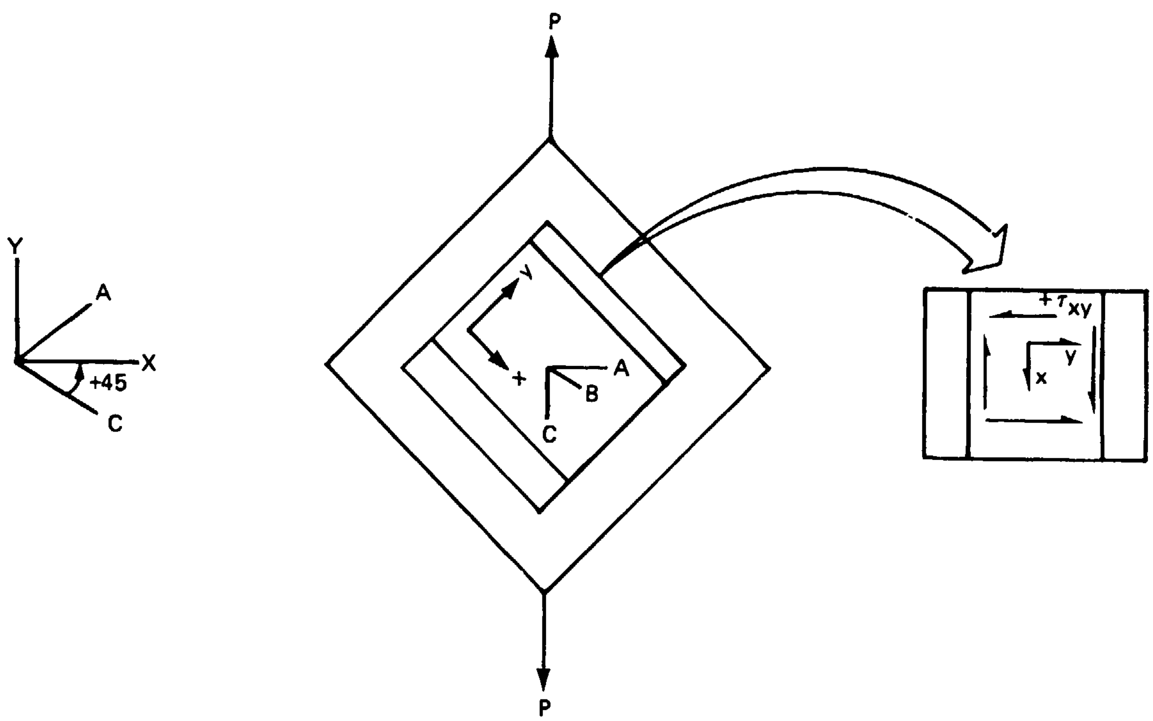

Table 2-16. Spar Web Shear Test (Test Panel No. 1)

Load increment	Load, kN	σ_x*	σ_y	τ_{xy}	Principal strains		
					ϵ_1	ϵ_2	γ_{12}
1	17.8	2.3	2.7	-22.5	0.00042	-0.00035	0.00077
2	35.6	14.9	15.3	-40.7	0.00093	-0.00046	0.00139
3	53.4	28.1	26.3	-58.3	0.00142	-0.00058	0.00200
4	71.2	44.0	40.4	-75.5	0.00195	-0.00064	0.00259
5	80.1	52.1	47.8	-84.0	0.00222	-0.00067	0.00289
6	89.0	60.2	55.2	-92.7	0.00249	-0.00070	0.00319
7	97.9	68.3	62.1	-101.3	0.00275	-0.00074	0.00349
8	106.8	76.1	69.4	-109.8	0.00302	-0.00077	0.00379
9	115.7	83.8	76.3	-118.4	0.00328	-0.00081	0.00409
10	124.6	91.4	83.0	-126.2	0.00353	-0.00083	0.00436
11	133.5	100.1	90.8	-135.4	0.00382	-0.00086	0.00468
12	142.4	108.1	96.7	-143.4	0.00407	-0.00091	0.00498

*Stress in MN/m^2

E_x = 20 685 MN/m^2
E_y = 20 685 MN/m^2
G_{xy} = 0.293 04 MN/m^2
V_{xy} = 0.68

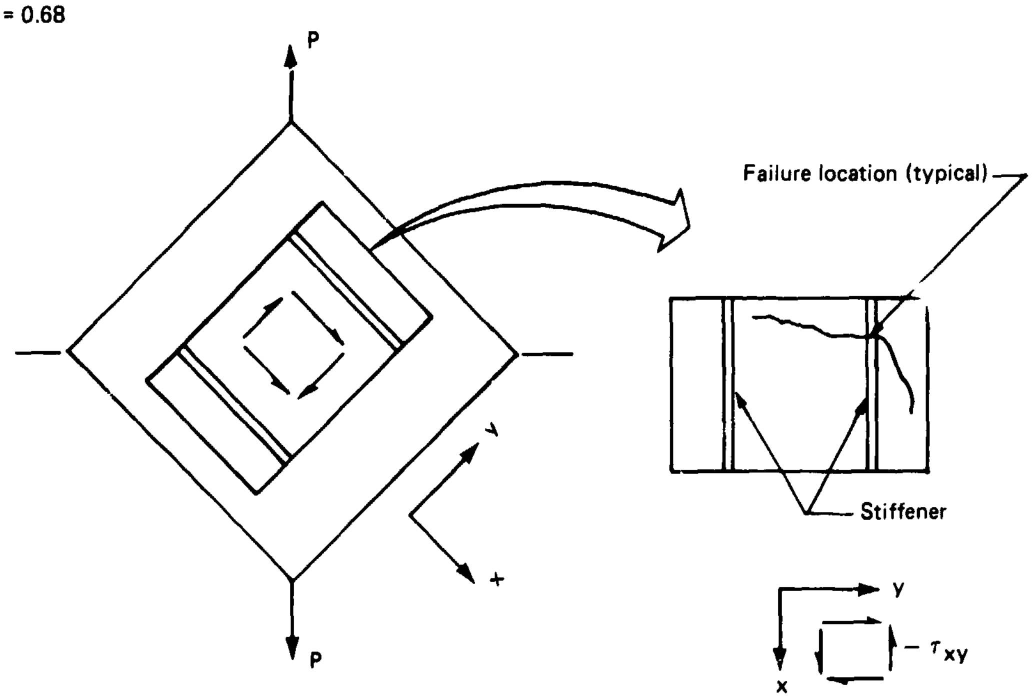

Table 2-17. Spar Web Shear Test (Test Panel No. 2)

Load increment	Load, kN	σ_x*	σ_y	τ_{xy}	Principal strains		
					ϵ_1	ϵ_2	γ_{12}
1	27.5	11.7	10.2	-29.8	0.00068	-0.00034	0.00103
2	54.6	33.4	28.6	-55.3	0.00144	-0.00048	0.00193
3	84.6	57.4	49.6	-82.7	0.00227	-0.00062	0.00289
4	111.3	81.4	71.2	-109.7	0.00310	-0.00074	0.00383
5	133.5	100.8	88.8	-131.5	0.00376	-0.00083	0.00459
6	154.4	119.8	106.0	-152.0	0.00440	-0.00091	0.00531

*Stress in MN/m^2

Table 2-18. Spar Web Shear Test (Test Panel No. 3)

Load increment	Load, kN	σ_x *	σ_y	τ_{xy}	Principal strains		
					ϵ_1	ϵ_2	γ_{12}
1	27.5	10.9	11.2	-34.4	0.00076	-0.00042	0.00118
2	54.0	34.4	33.4	-59.2	0.00154	-0.00049	0.00202
3	83.4	59.5	55.9	-83.5	0.00232	-0.00054	0.00286
4	111.3	85.6	78.8	-108.8	0.00315	-0.00060	0.00375
5	134.2	106.9	96.7	-129.5	0.00382	-0.00067	0.00449
6	150.3	122.1	110.2	-144.2	0.00430	-0.00071	0.00501

*Stress in MN/m^2

The average test failure shear stress was 146.5 MN/m^2, as compared with a maximum expected flight stress in the elevator front spar of 38 MN/m^2.

Typical moire fringe patterns, just prior to failure and just after failure, are shown in Figures 2-6 and 2-7.

Test No. 10—Honeycomb Panel Stability—Shear and compression panels have been tested. The panels measure approximately 56-cm square. The shear panel was tested in a picture-frame fixture, as shown in Figures 2-10 and 2-11. The compression panel had the top and bottom edges potted to prevent brooming at the load application point, and the vertical edges were simply supported. The test setup is shown in Figures 2-8 and 2-9.

The shear panel was expected to fail in shear prior to elastic buckling, and test results verified the failure mode. The first shear panel failed parallel to a panel edge, in the transition area from the honeycomb core edge to the laminate edge bond at a load of 100 kN/m, and the failure ran out of a corner radius of the panel as shown in Figure 2-19. The failure load is approximately 2-1/2 times the airplane panel design shear load. The next test specimen was modified to eliminate the corner radius. The failure is shown in Figures 2-12 and 2-13. The failure load was approximately the same as the original configuration load, but the failure mode was different, as shown. Further testing will be accomplished with the modified configuration.

Moire fringe evaluations were done on both the shear and compression tests, as shown in Figures 2-8 through 2-11.

Figure 2-6. Typical Moire Fringe Pattern Prior to Failure

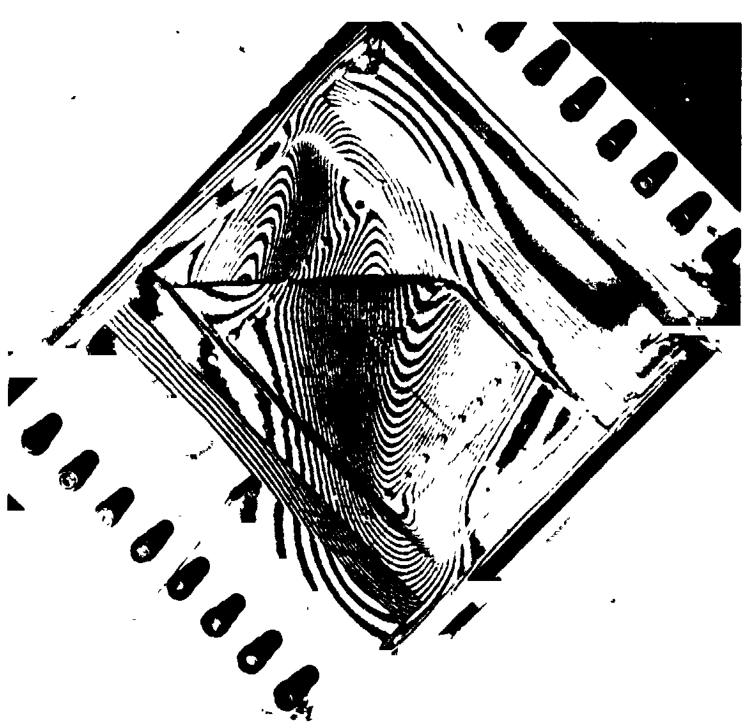

Figure 2-7. Typical Moire Fringe Pattern After Failure

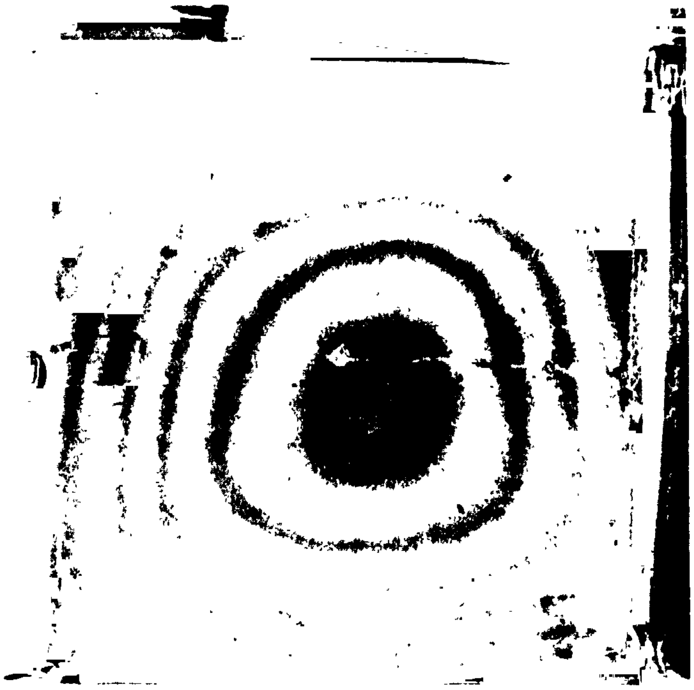

Figure 2-8. Honeycomb Panel Compression Test—Load = 13.3 kN

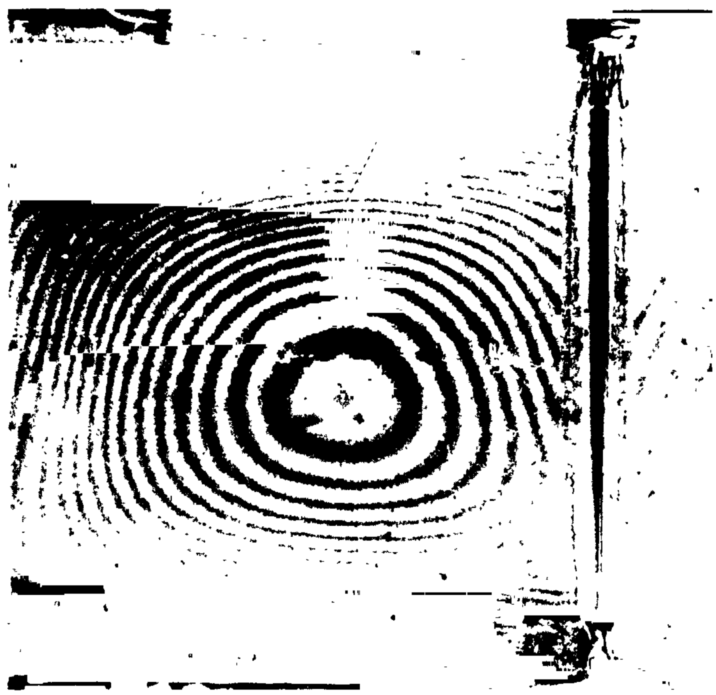

Figure 2-9. Honeycomb Panel Compression Test—Load = 39.9 kN

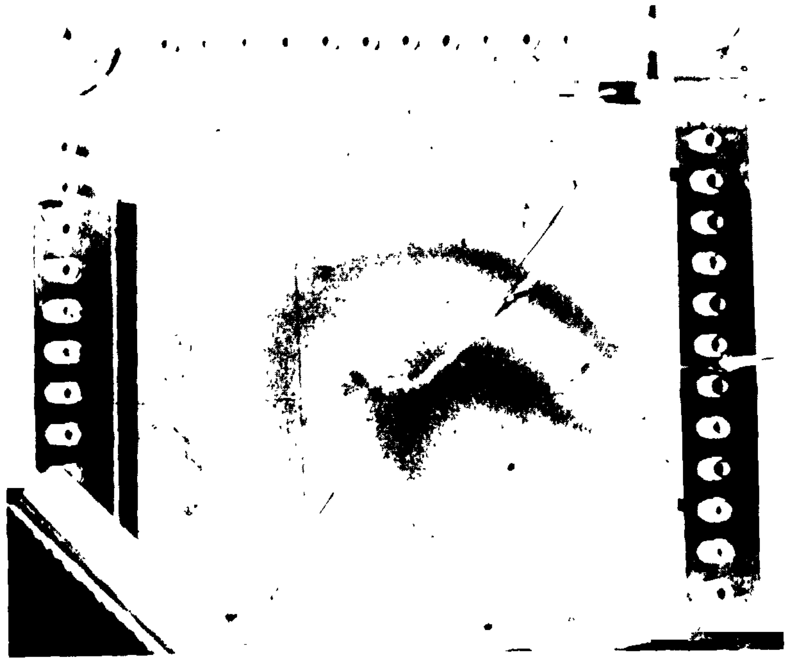

Figure 2-10. Honeycomb Panel Shear Test—Load = 22 kN

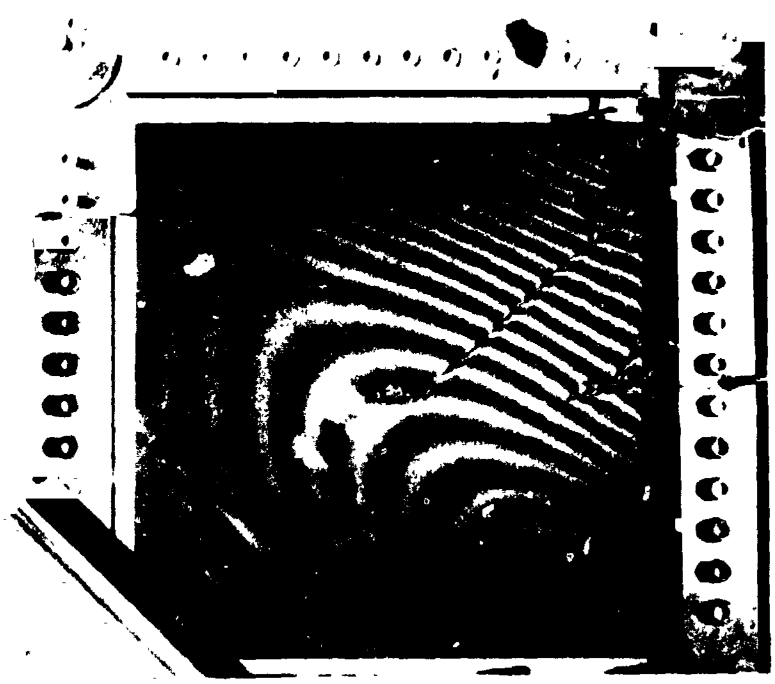

Figure 2-11. Honeycomb Panel Shear Test—Load = 80 kN

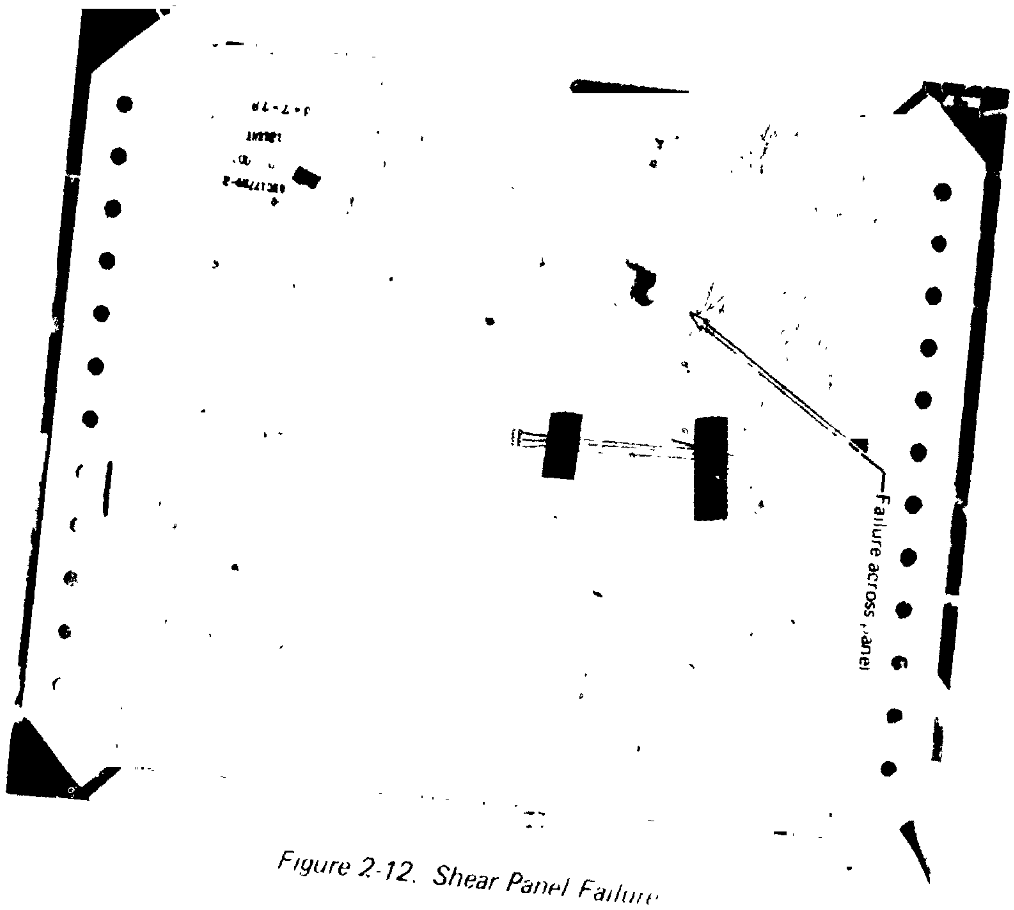

Figure 2-12. Shear Panel Failure

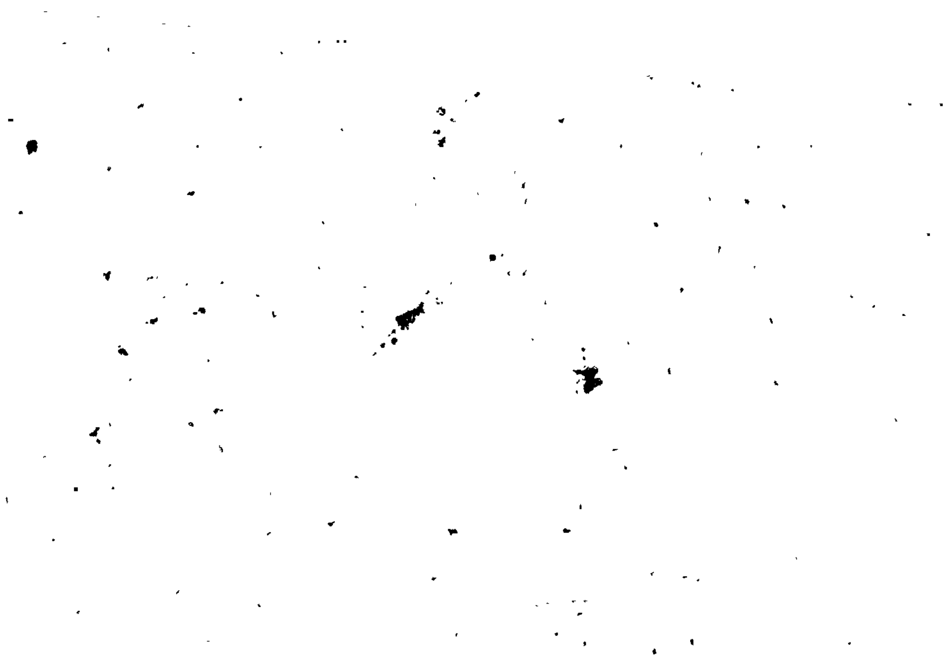

Figure 2 13. Shear Panel Failure

Typical compression panel failures occurred in the edge band, as shown in Figures 2-14, 2-15, and 2-16. The load at failure was approximately 700 N/cm (400 lb/in), or approximately twice the airplane panel design end load.

Strain gage results for the first shear and compression panel tests are shown in Tables 2-19 and 2-20.

The compression panel will be sectioned through the failure location, and examined in detail for failure mode.

Test No. 11—Spar/Aluminum Splice—The first of three front spar/actuator fitting splice test specimens was statically tested to failure at room temperature and dry (not preconditioned in moisture). The failure occurred in the tension flange at the end fastener common to the aluminum actuator fitting, as shown in Figures 2-17, 2-18, and 2-19.

The test specimen failed at approximately 80% of the predicted failure load. Post test analysis, using strain gage data just inboard of the failure, indicated that local splice eccentricity effects were greater than anticipated for the test specimen configuration. Although local lateral straps were used to stabilize the spar chords, the continuous skin support that will exist on the airplane elevator component was not duplicated in this test. The eccentricity effects will be greatly reduced on the full-scale hardware.

At the point of failure, the test load was equivalent to approximately 1.9 times the critical design ultimate load for a flight condition. In the test specimen spar constant section, the load at failure was equivalent to approximately 1.4 times the critical design ultimate load for a flight condition.

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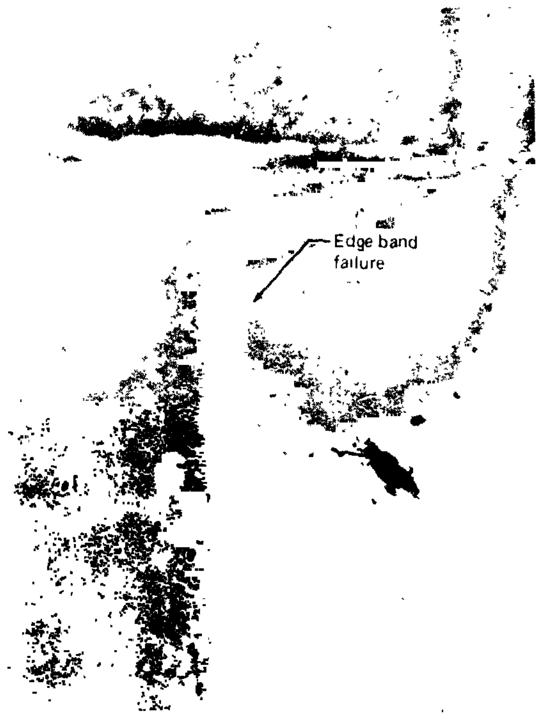


Figure 2-14. Compression Panel Failure (Edge Band)

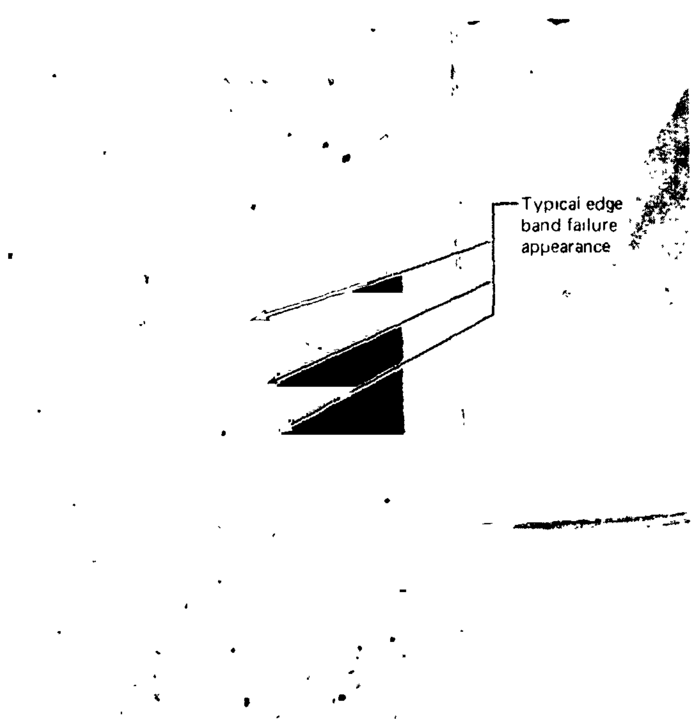


Figure 2-15. Compression Panel Failure (Normal View)

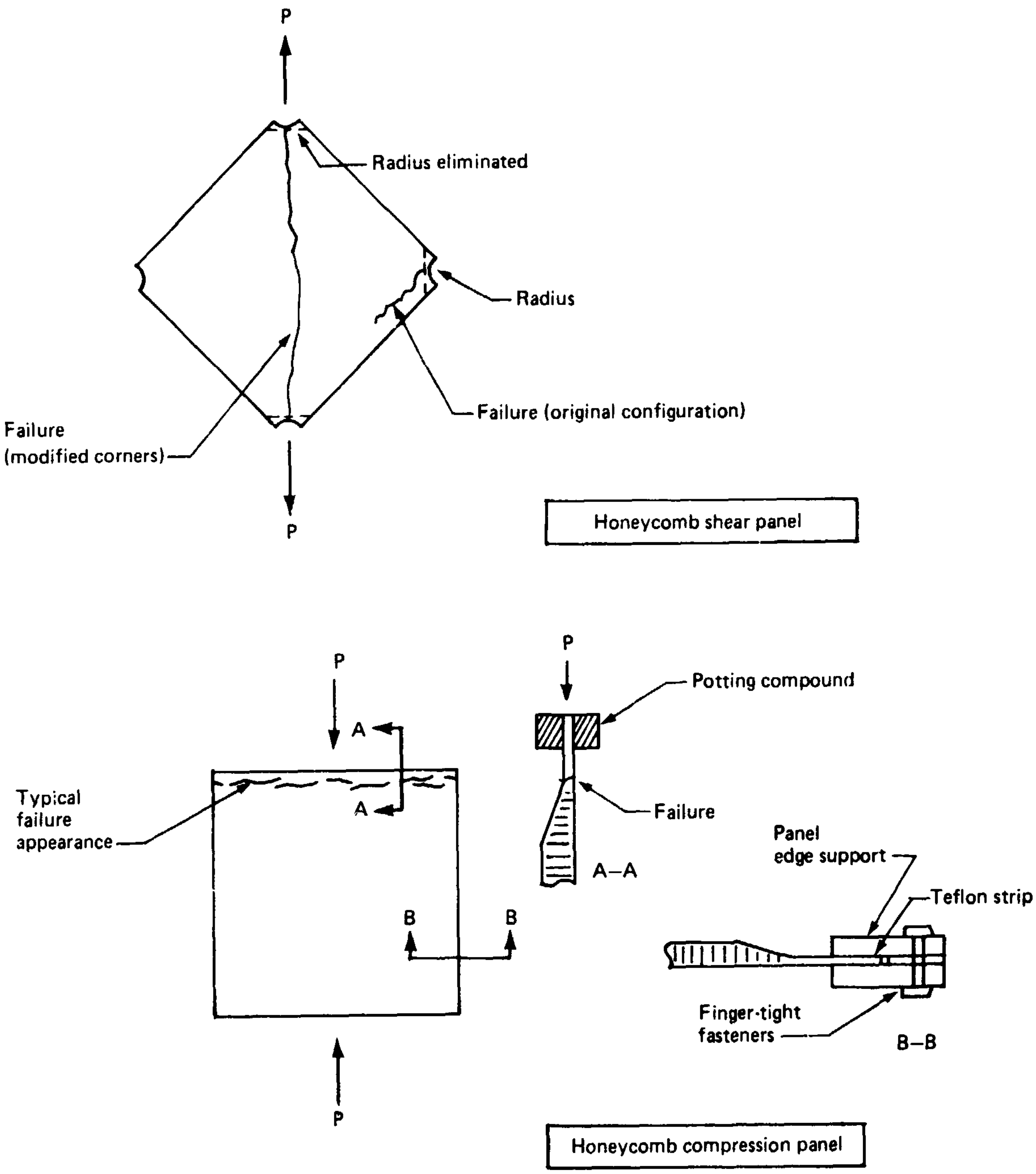


Figure 2-16. Failure in Panel Edge Band

Table 2-19. Honeycomb Panel Shear Test, 80.1 kN Load (Back-to-Back Gage Average)

Gage	σ_x *	σ_y	τ_{xy}	Principal strains		
				ϵ_1	ϵ_2	γ_{12}
1	-13.6	-28.0	199.9	0.00383	-0.00463	0.00846
2	30.2	20.3	192.8	0.00440	-0.00370	0.00810
3	74.3	53.1	161.8	0.00431	-0.00251	0.00681
4	9.3	5.7	157.1	0.00340	-0.00320	0.00660
5	53.5	30.6	164.2	0.00400	-0.00290	0.00690

*Stress in kN/m^2

$E_x = 54.5\ 10^3\ kN/m^2$
$E_y = 26.3\ 10^3\ kN/m^2$
$G_{xy} = 28.3\ 10^3\ kN/m^2$
$V_{xy} = 0.68$
$T_{face} = 0.267$ mm
$T_{core} = 14$ mm

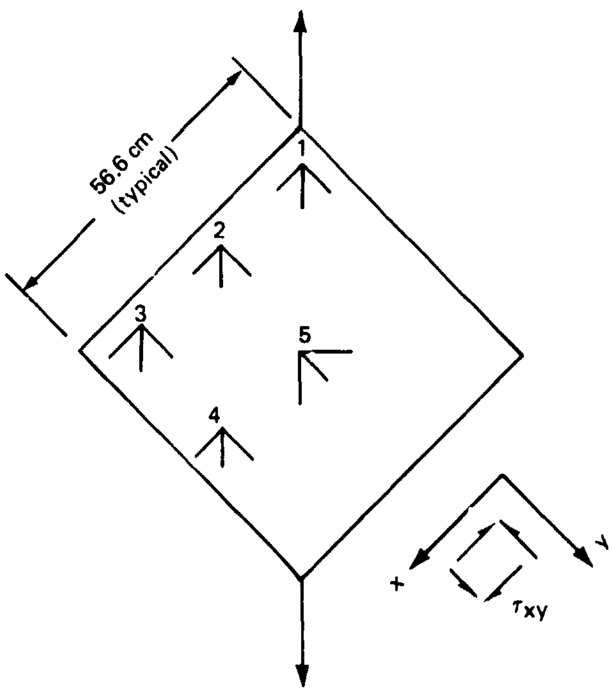
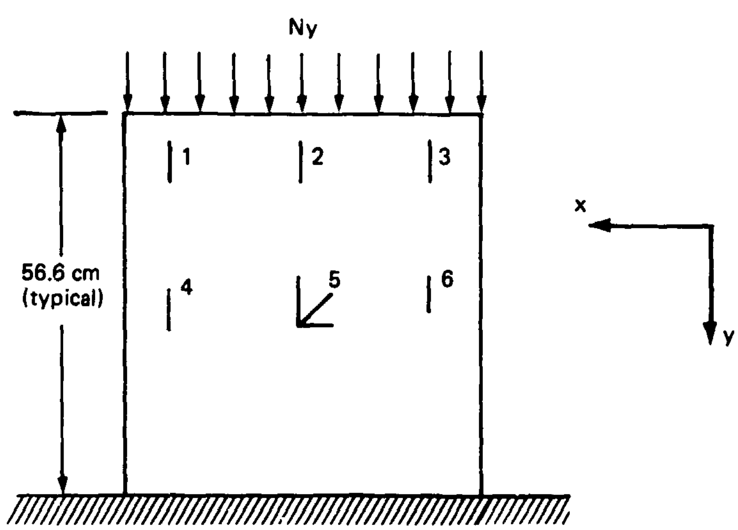


Table 2-20. Honeycomb Panel Compression Test, 41.6 kN Load (Back-to-Back Gage Average)

Gage	σ_x*	σ_y	τ_{xy}	Principal strains		
				ϵ_1	ϵ_2	γ_{12}
1	0.0	-65.5	0.0	0.00000	-0.00250	0.00000
2	0.0	-68.1	0.0	0.00000	-0.00260	0.00000
3	0.0	-70.7	0.0	0.00000	-0.00270	0.00000
4	0.0	-60.3	0.0	0.00000	-0.00230	0.00000
5	1.2	-70.3	0.0	0.00000	-0.00270	0.00360
6	0.0	-70.7	0.0	0.00000	-0.00270	0.00000

*Stress in MN/m^2

$E_x = 54.5\ 10^3\ kN/m^2$
$E_y = 26.2\ 10^3\ kN/m^2$
$G_{xy} = 23.8\ 10^3\ kN/m^2$
$V_{xy} = 0.68$
$T_{face} = 0.267$ mm
$T_{core} = 14$ mm



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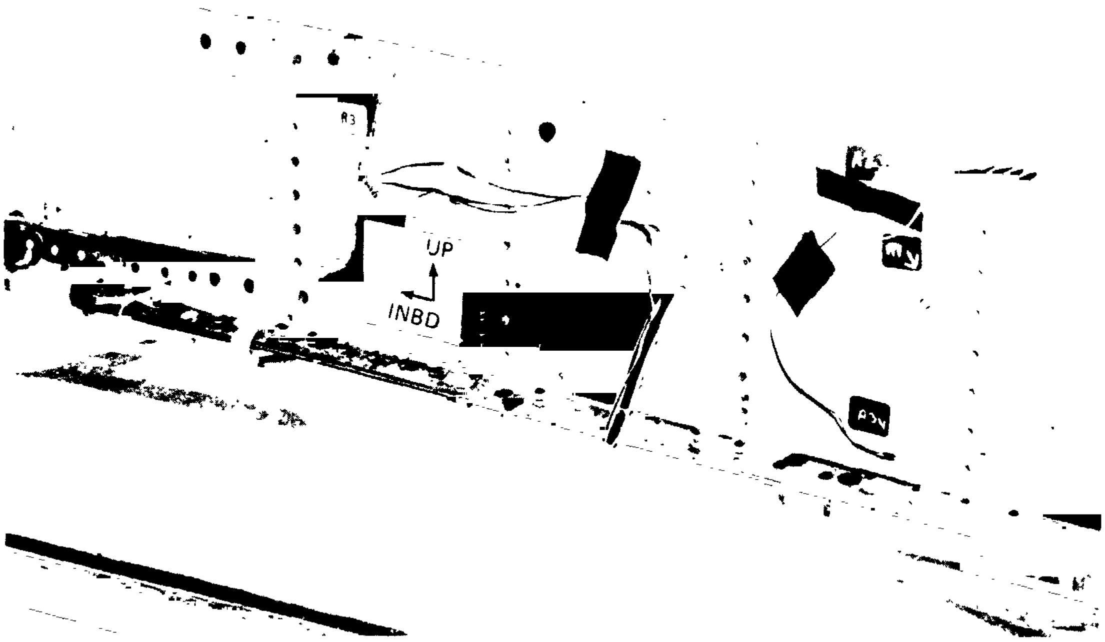

Figure 2-17. Front Spar/Actuator Fitting Splic Test Specimen Failure

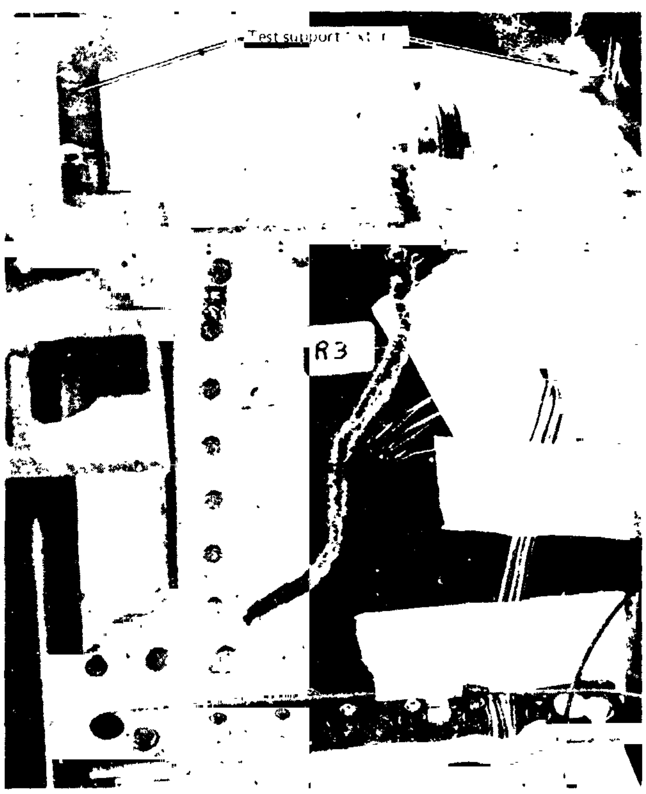

Figure 2-18. Front Spar/Act·:ator Fitting Splice Test Specimen Failure

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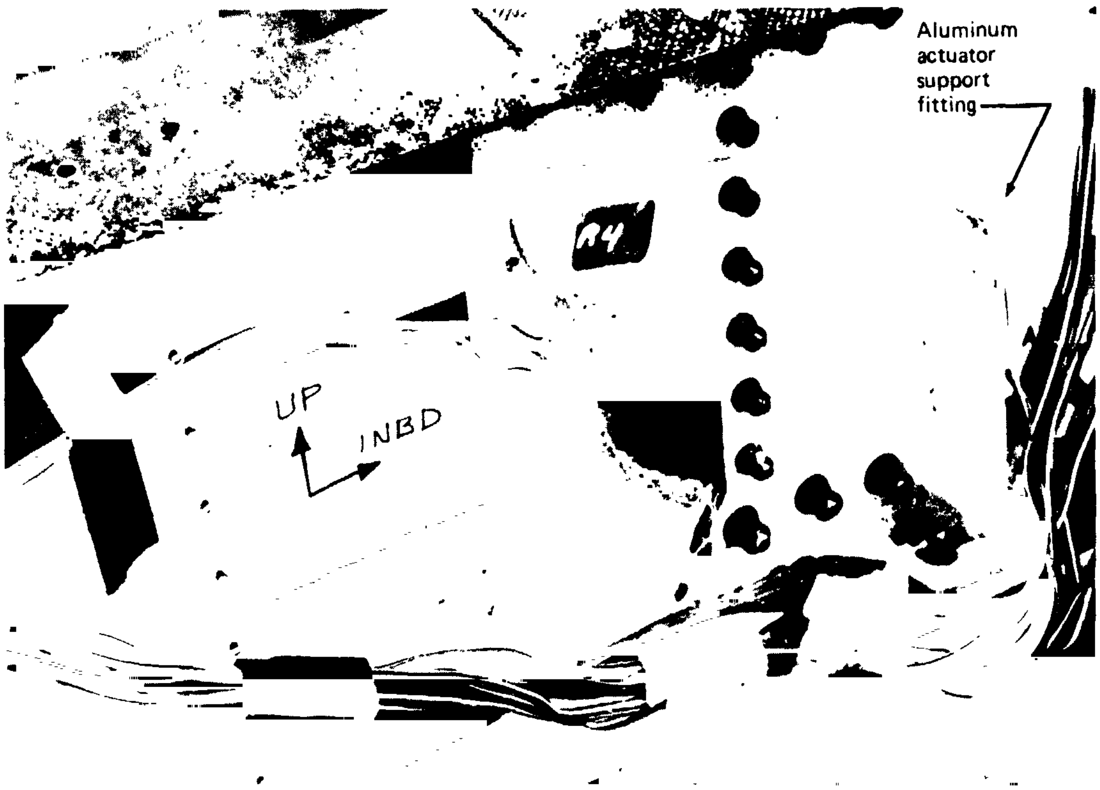

Figure 2-19. Front Spar/Actuator Fitting Splice Test Specimen Failure

Test No. 12—Panel Edge Shear and Bending—The setup for this test is shown in Figure 2-20. Test specimens were loaded to failure by applying either an upload as shown in Figure 2-20 or a download (not shown). The test failures to date typically occur away from the edge band in the honeycomb section. Preliminary results indicate the detail sustained approximately twice the airplane panel edge design load.

Test No. 14—Actuator Support Rib Verification—The actuator support rib test was completed in June. The test setup is shown in Figures 2-21, and 2-22, and the failed part in Figures 2-23, and 2-24.

The test specimen failed at approximately 1.06 times the predicted failure load. The test failure load was equivalent to approximately 3.5

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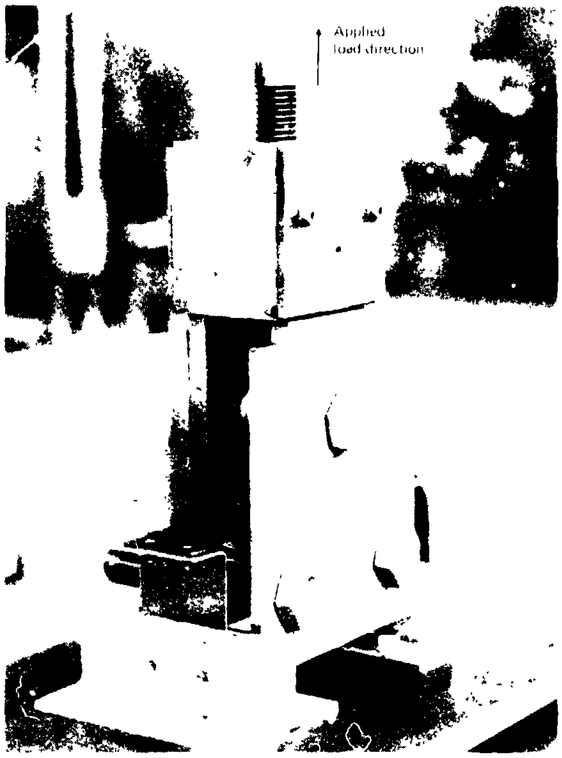

Figure 2-20. Panel Bending Test

Figure 2-21. Actuator Support Rib Test

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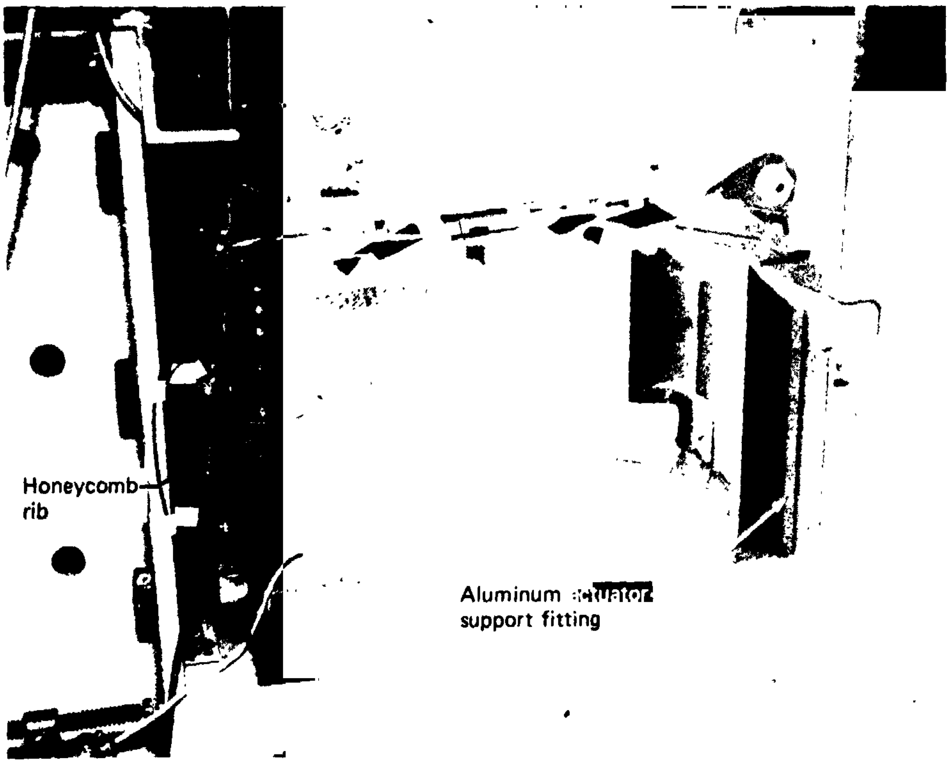

Figure 2-22. Actuator Support Rib Test

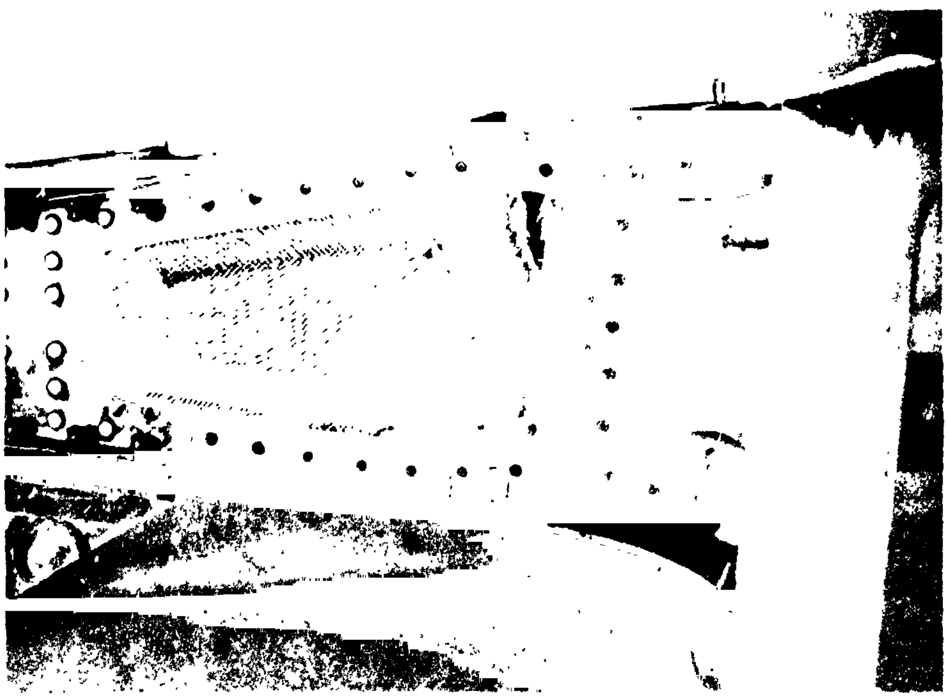

Figure 2-23. Actuator Support Rib Failure

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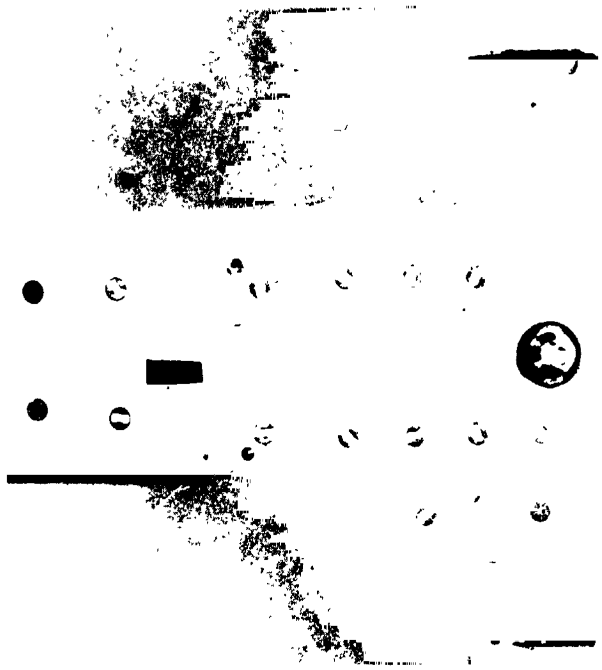

Figure 2-24. Actuator Support Rib Failure

times the actuator capacity on the airplane component. The graphite/epoxy rib was sized to achieve approximately the same stiffness and strength as the current metal design, which was designed to approximately 3.0 times the airplane actuator capacity.

Test No. 15—First Sonic Box—Testing of the first sonic box has been completed. In summary, the box was tested for 15 hr at 155 dB (overall) and 4 hr at 158 dB (overall). This testing represented two lifetimes of in-service accumulated damage. The box was then damaged by impacting the honeycomb panel and edge bands at 12 locations. The damaged areas were evaluated, using a hand-held ultrasonic inspection instrument. The box was then tested for an additional in-service lifetime (4 hr at 158 dB overall). Post-test inspection revealed no apparent propagation of the damaged areas.

A detailed presentation of data will be given when the laboratory test report is complete.

Test No. 17—Outboard Test Box (10-ft box)—Testing was begun on this test article in mid-July. Torsional and bending stiffnesses are being evaluated. Testing will include subjecting the test article to the design ultimate load, and is planned for completion by the end of August.

A finite element model of the test article, as it is supported and loaded during test, is planned. The model will be extracted from the overall elevator finite element model. Strain gage and deflection results will be compared to calculated values for finite element model analysis verification.

Test No. 18—Rear Spar Sonic Box—Testing of the rear spar sonic box has been completed. This box was the same overall size as the Test No. 15 box, but incorporated a rear spar instead of a tapered, closed trailing edge. The box was tested for 8 hr at 158 dB (overall), and then damaged by impacting the panel and rear spar at a total of 18 locations. An additional 4 hr of testing at 158 dB (overall) did not cause any apparent propagation of the inflicted damage.

2.3 DESIGN

Project is continuing to perform design-sustaining activity. The majority of the work is not involved in changing part-configuration, but it is providing drawing interpretation and clarification, correcting drawing errors and inconsistancies, and incorporating manufacturing requests to simplify fabrication of parts. However, two design changes were made. The first change was made on the transverse horn rib (65C17536), where the rib flanges were found to be inadequate when additional detail stress analyses were conducted. Excessive flange bending was encountered in reacting the horn weight design loads into the web of the transverse rib. This bending was corrected by nesting 0.18-cm (0.071-in) thick aluminum angle reinforcing clips against the rib inside mold line at each end of the rib at both the upper and lower flanges.

The second design change involved the ply buildup of the rear spar detail (65C17546-3). The first production rear spar detail had an unacceptable spanwise warpage of 0.91 cm (0.36 in). This warpage was diagnosed as resulting from differential thermal contraction between the web and the flanges of the rear spar. The aft portion of the flanges contained a stiffener insert (65C17546-11), which was constructed of 100% spanwise (0°) fiber. Also, the outside ply in the aft portion of the flanges was 100% spanwise fiber. The remainder of the spar was essentially of a quasi-isotropic layup (25% 0°; 50% 45°; 25% 90°). The thermal contraction of the 100% 0° fibers is much less than that of the quasi-isotropic construction. Thus, when cool-down from the $350^{\circ}F$ curing temperature takes place, warpage occurs. The fix was to build the stiffener insert with a quasi-isotropic fabric layup, and to make the outside ply, which had previously been spanwise tape, one ply of 0° or 90° fabric. A spar of the new layup configuration has been fabricated and the warpage has been eliminated.

2.4 WEIGHT STATUS

The current weight status of the advanced composites elevator system is shown in Table 2-21. These weight data contain the following changes:

(1) Corrosion protection, which has previously been identified as a line item, has been partially distributed to the following items:

Front and rear spars	1.3 kg (2.9 lb)
Ribs	0.1 kg (0.3 lb)
Skin panels	0.7 kg (1.6 lb)
Control tab	0.1 kg (0.2 lb)

The corrosion protection line item has been reduced by a like amount.

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Table 2-21. Predicted Weight Status

Item	1 Aluminum baseline, kg (lb)/airplane		2 Advanced composites system weights: Previous report, kg (lb)/airplane		3 Current report, kg (lb)/airplane		4 Δ Previous to current, kg (lb)/airplane 2 − 3		5 Weight difference, kg (lb)/airplane 1 − 3		6 % Weight difference, $\frac{1-3}{1} \times 100$
Front and rear spars	35.2	(77.7)	26.3	(58.0)	27.9	(61.5)	+1.6	(+3.5)	−7.3	(−16.2)	−21
Ribs	12.0	(26.6)	6.7	(14.7)	6.6	(14.6)	0	(−0.1)	−5.4	(−12.0)	−45
Skin panels	52.8	(116.3)	43.9	(96.7)	44.6	(98.3)	+0.7	(+1.6)	−8.2	(−18.0)	−15
Control tab	11.1	(24.4)	5.8	(12.7)	6.3	(13.8)	+0.5	(+1.1)	−4.8	(−10.6)	−43
Horn structure	6.0	(13.2)	3.6	(8.0)	3.6	(8.0)	0	(0)	−2.4	(−5.2)	−39
Corrosion protection	0	(0)	2.8	(6.3)	0.6	(1.3)	−2.3	(−5.0)	+0.6	(+1.3)	—
Lightning protection	0	(0)	1.2	(2.7)	1.2	(2.7)	0	(0)	+1.2	(+2.7)	—
Replaced structure	117.1	(258.2)	90.3	(199.1)	90.8	(200.2)	+0.5	(+1.1)	−26.3	(−58.0)	−22
Balance panel weights	32.0	(70.6)	0	(0)	0	(0)	0	(0)	−32.0	(−70.6)	−100
Balance panel hinges	54.6	(120.3)	35.5	(78.3)	38.3	(84.6)	+2.9	(+6.3)	−16.2	(−35.7)	−30
Horn balance weight	18.8	(41.5)	23.6	(52.0)	23.6	(52.0)	0	(0)	+4.8	(+10.5)	+25
Elevator adjust weights	0	(0)	1.8	(4.0)	2.3	(5.0)	+0.5	(+1.0)	+2.3	(+5.0)	—
Nose ribs and skins	18.9	(41.6)	18.1	(39.8)	20.1	(44.3)	+2.0	(+4.5)	+1.2	(+2.7)	+6
Balance panel structure	16.0	(35.2)	16.0	(35.2)	16.2	(35.7)	+0.2	(+0.5)	+0.2	(+0.5)	+1
Revised structure	140.3	(309.2)	95.0	(209.3)	100.5	(221.6)	+5.6	(+12.3)	−39.7	(−87.6)	−28
Total elevator system weight/airplane	257.4	(567.4)	185.3	(408.4)	191.3	(421.8)	+6.1	(+13.4)	−66.0	(−145.6)	−26

(2) The following items have been updated to reflect production drawing predictions:

Front and rear spars	+0.3 kg (+0.6 lb)
Ribs	-0.2 kg (-0.4 lb)
Control tab	+0.4 kg (+0.9 lb)
Balance panel hinges	+2.9 kg (+6.3 lb)
Elevator adjust weights	+0.5 kg (+1.0 lb)
Nose ribs and skins	+2.0 kg (+4.5 lb)
Balance panel structure	+0.2 kg (+0.5 lb)

Total weight of the advanced composites elevator system is now 191.3 kg (421.8 lb), and the overall weight reduction is 26%.

2.4.1 Actual Weight Program

Actual weight data of graphite/epoxy production detail parts are being analyzed, and will be reported when completed.

2.4.2 Static Balance Requirements Document

The Static Balance Requirements Document, D6-46023, has been compiled and is being reviewed, prior to preliminary issue.

The document details static balance requirements for the total elevator system, the weight requirement of each balance panel, the required moment of the elevator surface, and weight and balance requirements of the control tab.

SECTION 3.0

OPERATIONS DEVELOPMENT

This section discusses results of the manufacturing producibility studies, ancillary test hardware fabrication, quality assurance development, and verification hardware manufacture.

3.1 PRODUCIBILITY STUDIES

Manufacturing requested a producibility study of the rear spar (65C17546-3), because the detail as fabricated warped 0.91 cm (0.36 in) in the spanwise direction. A review of the problem indicated the precured graphite/epoxy filler of 100% fibers in the spanwise direction was causing most of the problem. Engineering changed the graphite/epoxy filler to a quasi-isotropic layup of fabric. At the same time, the exterior graphite/epoxy tape ply was also changed to fabric.

A second rear spar was fabricated and trimmed using the new construction. The second rear spar had a warpage of 0.13 cm (0.050 in) in the spanwise direction as compared to 0.86 cm (0.36 in) for the first spar. The 0.13-cm (0.050-in) spanwise warpage is acceptable, and can be removed with slight hand pressure.

3.2 ANCILLARY TEST COMPONENT FABRICATION

The ancillary test program includes allowables and environmental, concept verification, and repair. The following describes the fabrication and assembly status.

3.2.1 Allowables and Environmental

This part of the ancillary test program includes coupons (Test No. 1), joint/elements (Test No. 4), and environmental specimens (Test No. 3).

All allowable and environemntal specimens have been fabricated and assembled.

3.2.2 Concept Verification

This part of the ancillary test program includes panel/rib pad (Test No. 8), spar/shear web (Test No. 9), honeycomb panel stability (Test No. 10), spar/aluminum splice (Test No. 11), panel edge spar (Test No. 12), rib design (Test No. 14), sonic test box (Test No. 15), 10-ft outboard test box (Test No. 17), second sonic test box (Test No. 18).

All concept verification hardware has been fabricated and assembled for testing.

Figure 3-1 shows the 10-ft outboard test box (Test No. 17) during assembly. Figures 3-2 through 3-6 show the second sonic test box (Test No. 18) during fabrication and assembly.

3.3 QUALITY ASSURANCE DEVELOPMENT

This section discusses the Preliminary Standards, Production Standards, Fabrication Method, NDI techniques, Test Results, and Conclusions.

3.3.1 Preliminary Standards

Preliminary standards were designed to represent the anticipated production design, and were fabricated per BAC 5562. The following preliminary standards were built:

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Figure 3-1. Assembly of Test No. 17 Outboard Test Box, Showing Assembled Lower Skin, Ribs, and Rear Spar

Figure 3-2. Second Sonic Box, Test No. 18 Skin Panel, Showing Outer Skin Plies in Place

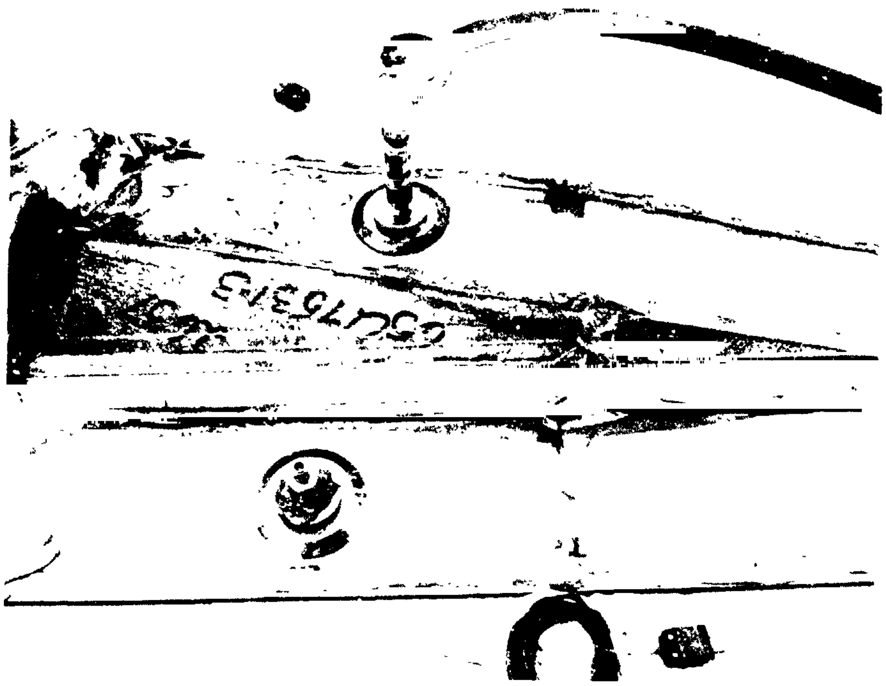


Figure 3-3. Second Sonic Box, Test No. 18, Showing Honeycomb Rib Ready for Cure

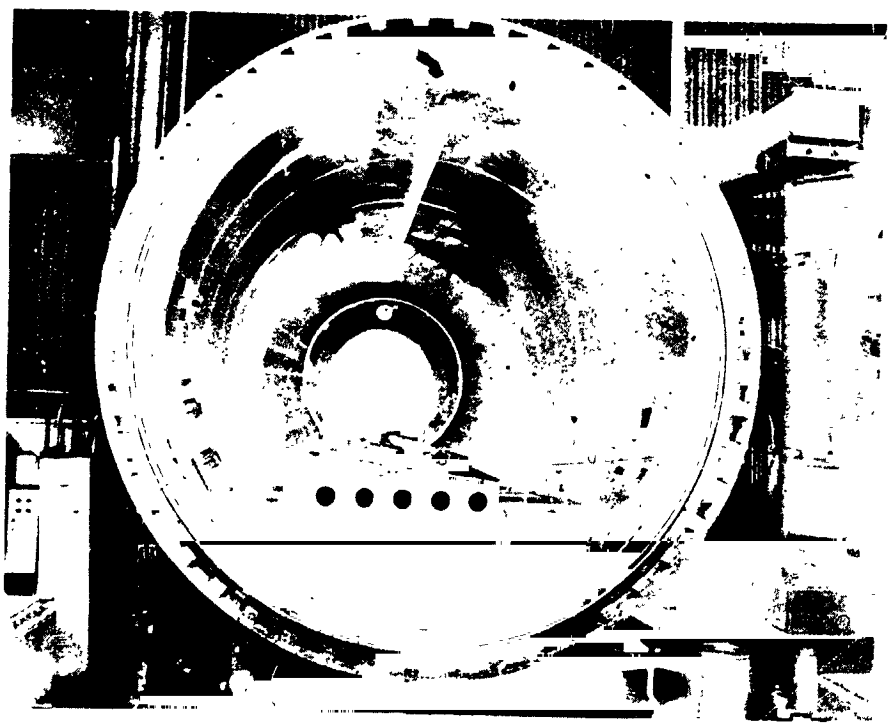


Figure 3-4. Second Sonic Box, Test No. 18, Showing Skin Panel in Autoclave

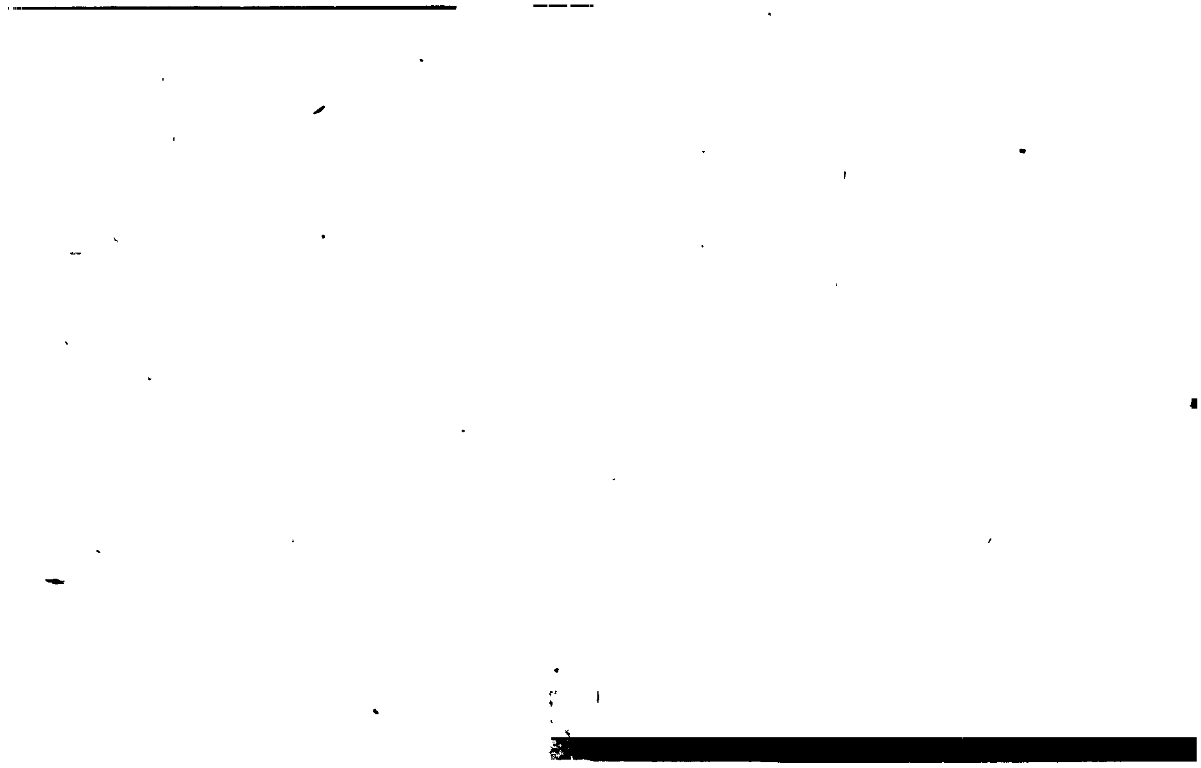


Figure 3-5. Second Sonic Box, Test No. 18, Showing Front View of Completed Assembly

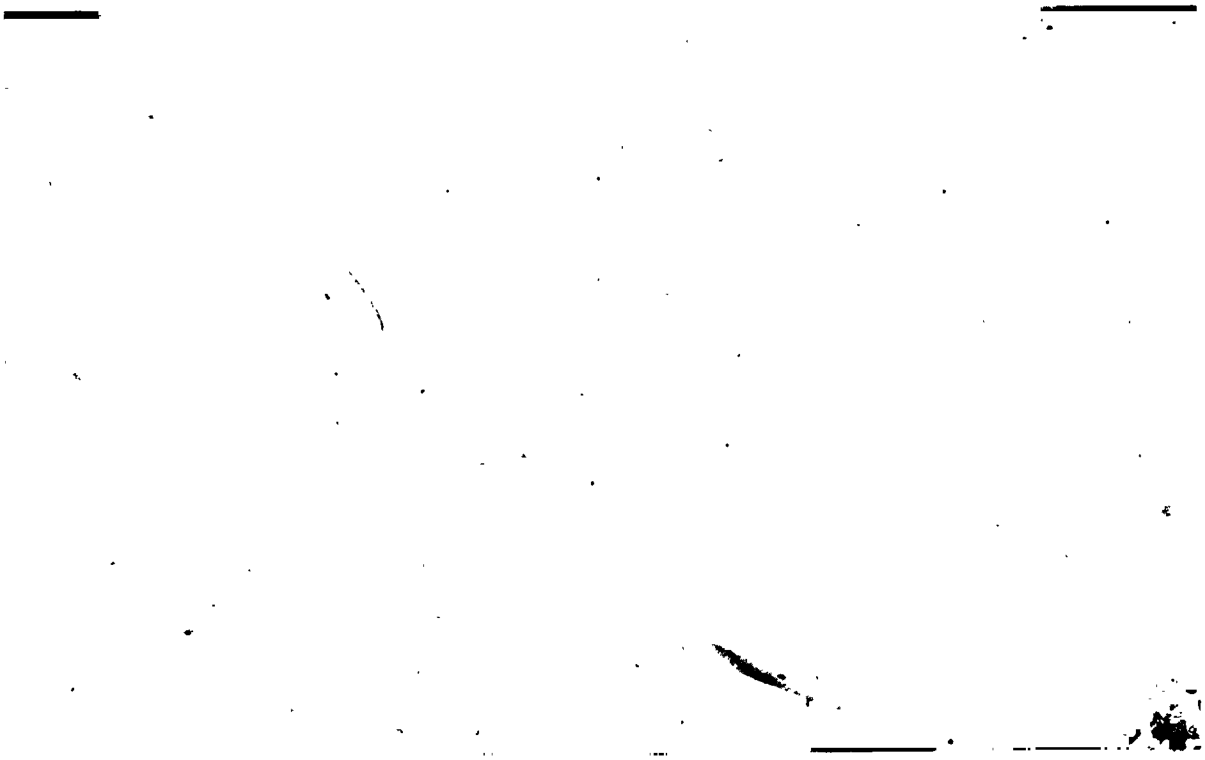


Figure 3-6. Second Sonic Box, Test No. 18, Showing Rear View of Completed Assembly

- Laminate Standard—This standard was built with 0.64- x 0.64-cm (0.25- x 0.25-in) defects. It was required to qualify NDI techniques per Boeing Advanced Composites Process Specification (BAC 5562). See Figure 3-7 for details.

- Honeycomb Standard—This standard was built with 0.64- x 0.64-cm (0.25- x 0.25-in) defects. It was required to qualify NDI techniques per BAC 5562. See Figure 3-8 for details.

- Laminate Step Standard—This standard consists of eight laminate steps with 0.64- x 0.64-cm (0.25- x 0.25-in) and 1.27- x 1.27-cm (0.5- x 0.5-in) defects in each step. The thickness of steps are 2P, 4P, 6P, 8P, 10P, 12P, 14P, and 15P. See Figure 3-9 for details.

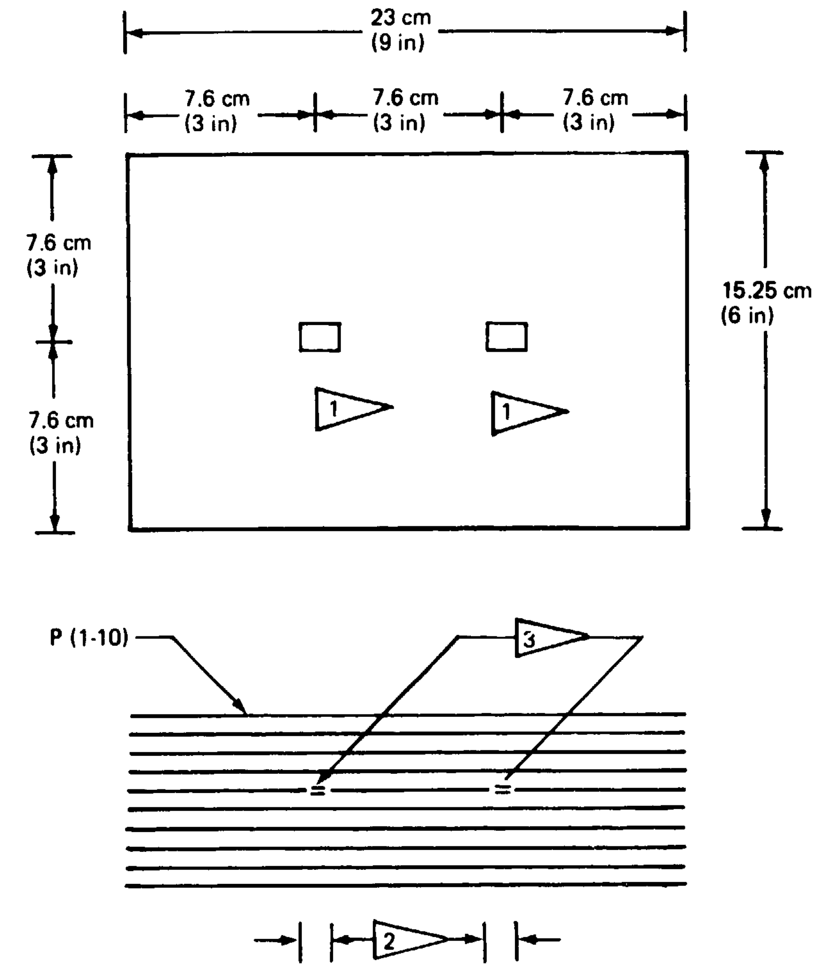
- Front Spar Chord Standard—This standard has 1.27- x 1.27-cm (0.5- x 0.5-in) defects in various thickness levels. The details are shown on Figure 3-10 .

- Skin Panel Standard—This standard has 0.64- x 0.64-cm (0.25- x 0.25-in), 1.27- x 1.27-cm (0.5- x 0.5-in), and 2.54- x 2.54-cm (1- x 1-in) defects. The standard was designed to duplicate upper and lower skin panels. The details are shown on Figure 3-11.

- Taper Edge Standard—This standard was designed to investigate defects in the taper area of the skin panels. The defect sizes were 1.27 x 1.27 cm (0.5 x 0.5 in) and 2.54 x 2.54 cm (1 in x 1 in). The details are shown on Figure 3-12.

3.3.2 Production Standards

Production NDI standards with built-in defects were designed to duplicate exactly the various sections of the production parts, and were fabricated in accordance with BAC 5562. Following is a list of the production standards:



Ply No.	Orientation
1	0°
2	+45°
3	0°
4	-45°
5	0°
6	0°
7	-45°
8	0°
9	+45°
10	0°

10 Plies
BMS 8-212
Type II
Class 2
Style 3K-70-P

1. 0.64-cm^2 (0.25-in^2) disbond
2. 0.64-cm^2 (0.25-in^2) fabric cutout
3. Two 0.64-cm^2 (0.25-in^2) Teflon shims—2 mil

Fabricate per BAC 5562

Figure 3-7. NDI Reference Standard—Graphite/Epoxy Laminate

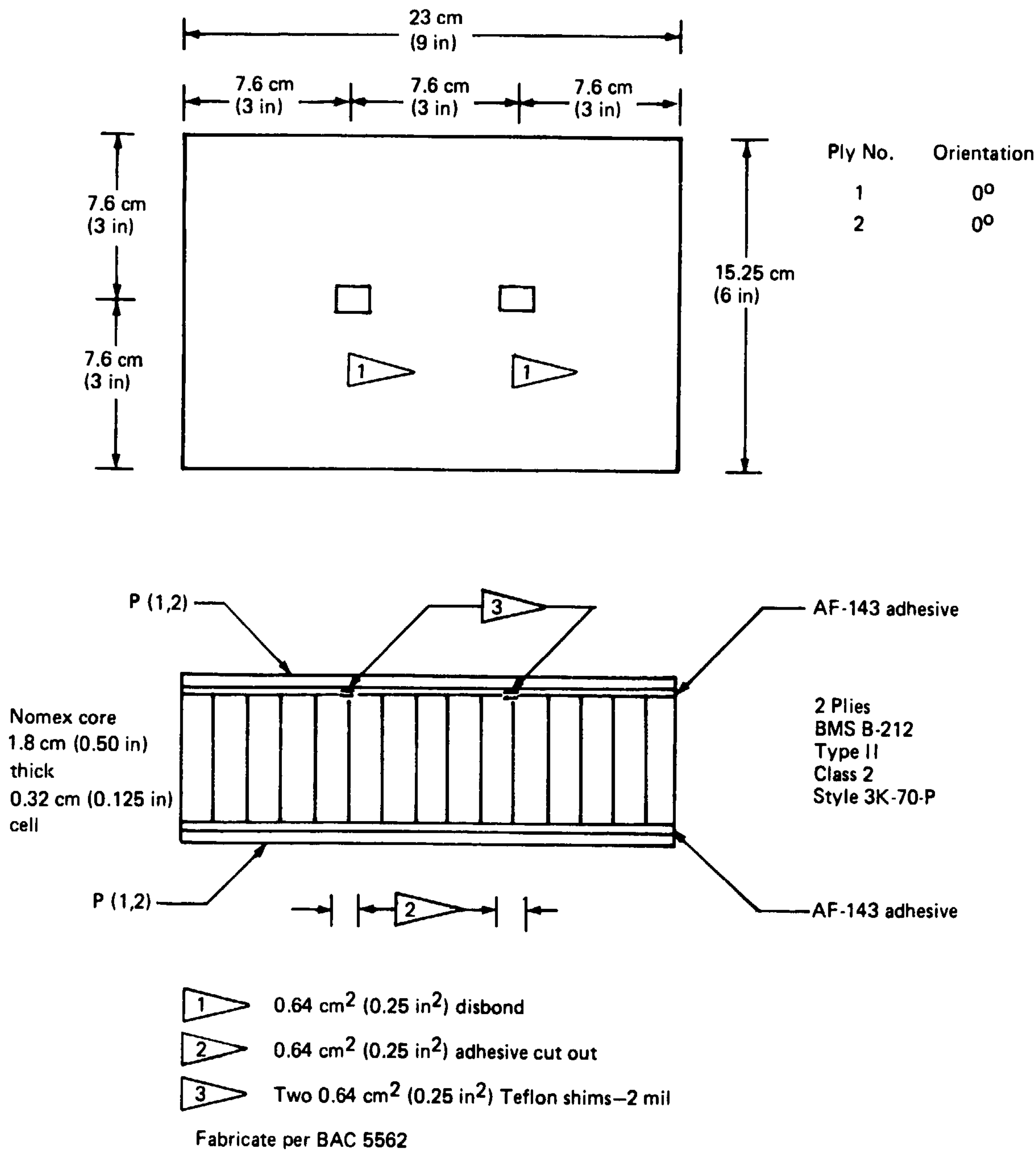
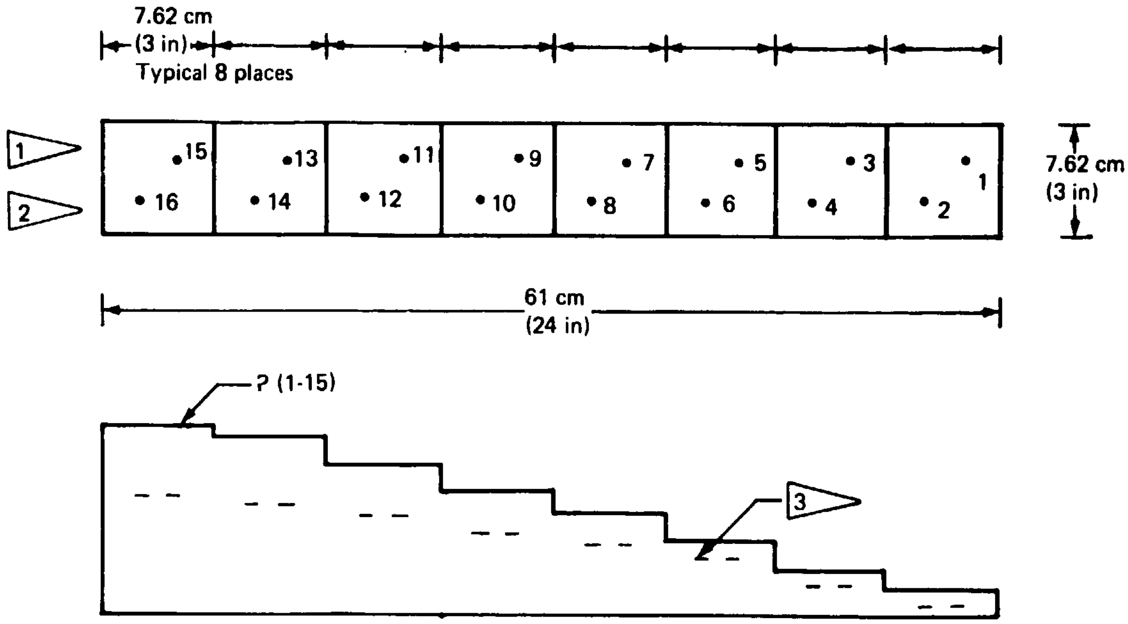


Figure 3-8. NDI Reference Standard—Graphite/Epoxy Honeycomb



Defect No. 1 and 2 Between P1 and P2
Defect No. 3 and 4 Between P3 and P4
Defect No. 5 and 6 Between P4 and P5
Defect No. 7 and 8 Between P5 and P6
Defect No. 9 and 10 Between P6 and P7
Defect No. 11 and 12 Between P7 and P8
Defect No. 13 and 14 Between P8 and P9
Defect No. 15 and 16 Between P9 and P10

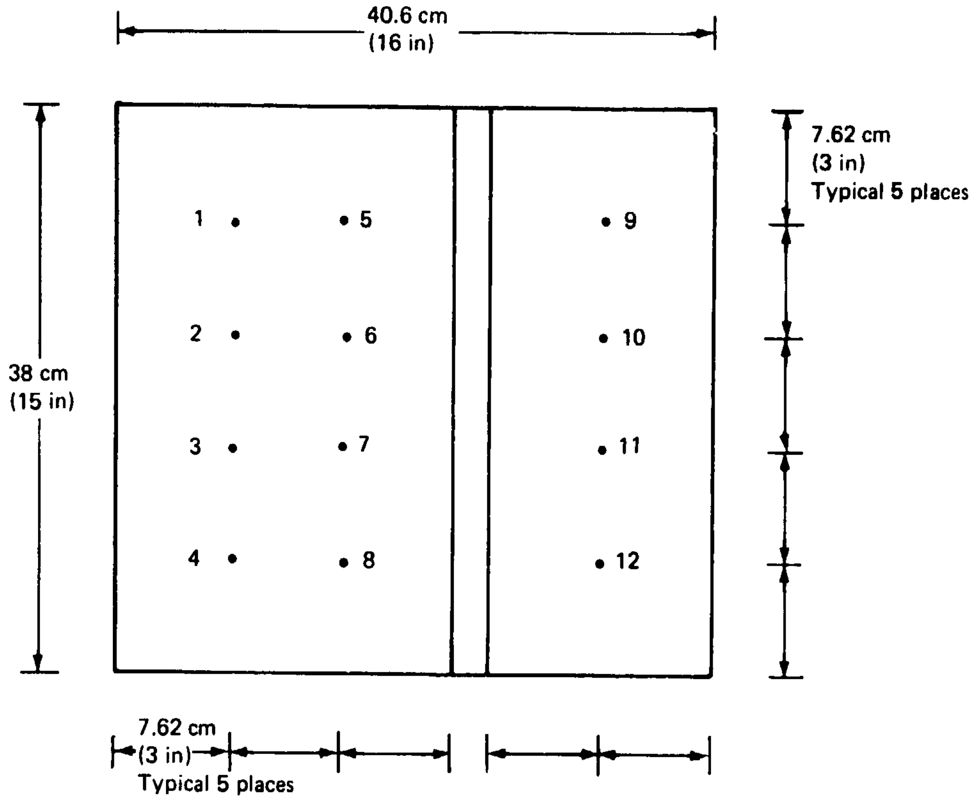
Material:

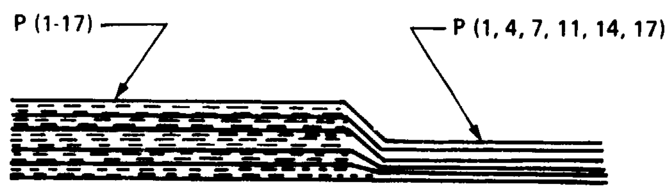
BMS 8-212
Type II, Class 2
Style 3K-70-P

1 0.64 x 0.64-cm (0.25 x 0.25-in) defect
2 1.27-cm x 1.27-cm (0.5 x 0.5-in) defect
3 Two 0.005-cm (0.002-in) Teflon shims of specified defect size

Ply No.	Orientation	Ply No.	Orientation
1	0°	8	$+45^\circ$
2	$+45^\circ$	9	0°
3	90°	10	90°
4	0°	11	-45°
5	-45°	12	0°
6	90°	13	90°
7	0°	14	$+45^\circ$
		15	0°

Figure 3-9. Laminate Step Standard





6 plies (fabric

Material:

BMS 8-212
Type II, Class 2
Style 3K-70-P

11 plies (tape)

Material:

BMS 8-212
Type II, Class 1
Grade 145

All defects 1.27 x 1.27-cm (0.5 x 0.5-in) 2-mil Teflon shims

Defect No. 1 Between P17 and P16
Defect No. 2 Between P16 and P15
Defect No. 3 Between P15 and P14
Defect No. 4 Between P14 and P13
Defect No. 5 Between P13 and P12
Defect No. 6 Between P12 and P11
Defect No. 7 Between P11 and P10
Defect No. 8 Between P10 and P9
Defect No. 9 Between P17 and P14
Defect No. 10 Between P14 and P11
Defect No. 11 Between P11 and P7
Defect No. 12 Between P7 and P4

Figure 3-10. Front Spar Chord Standard

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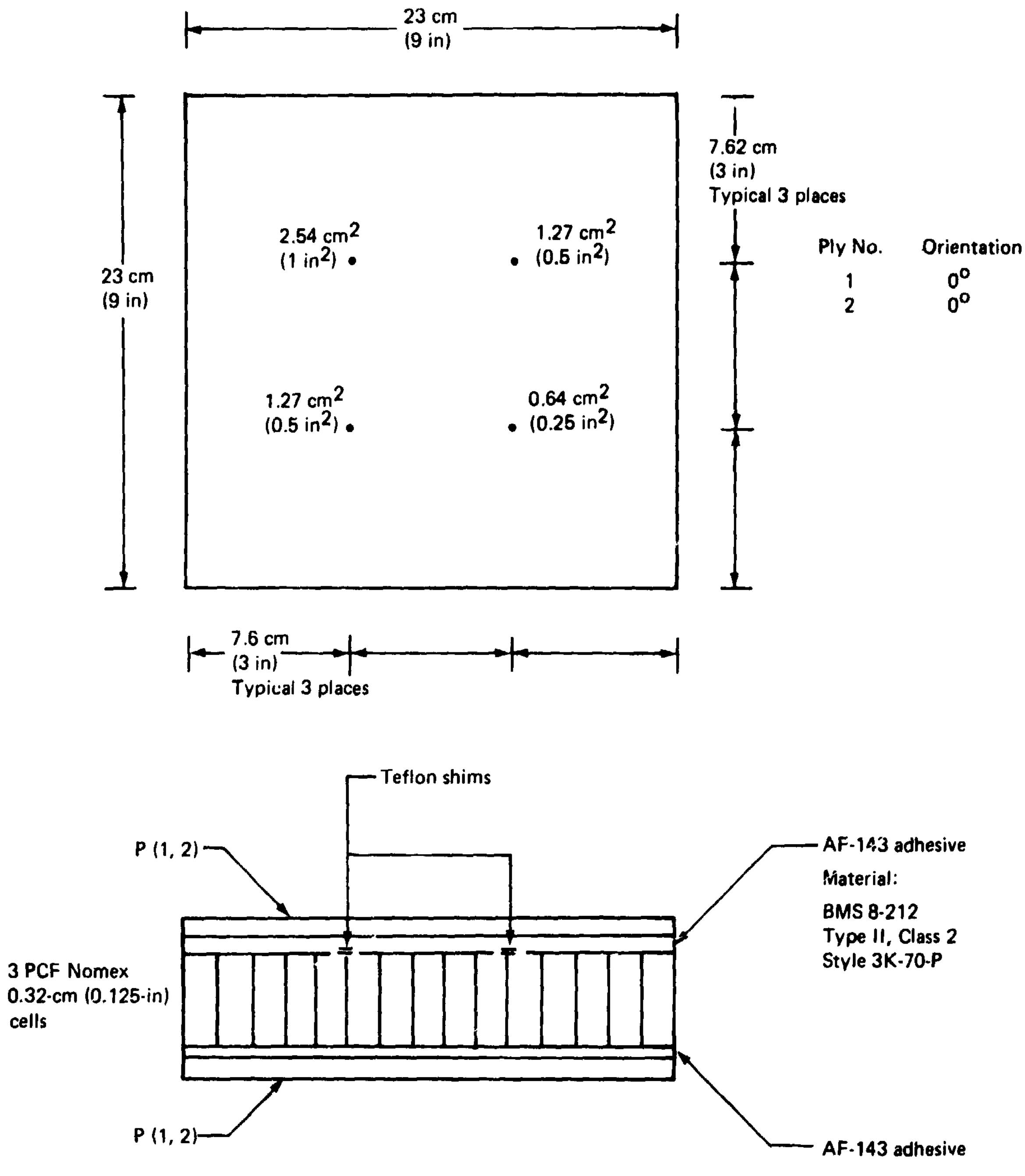
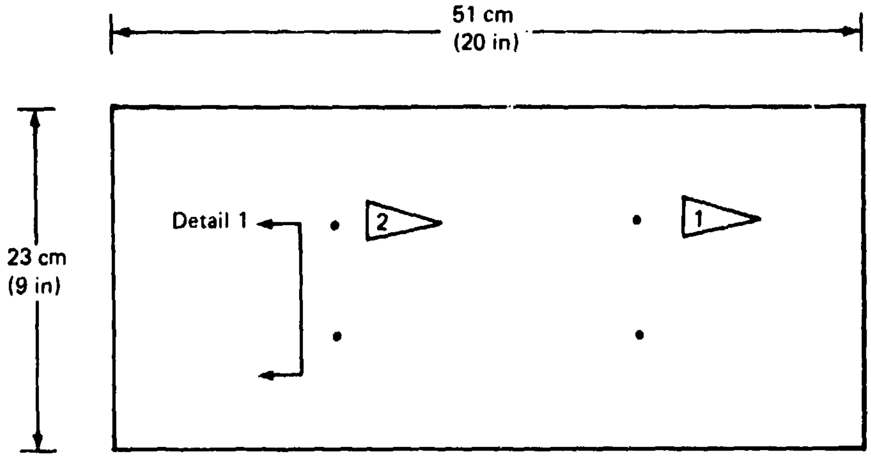
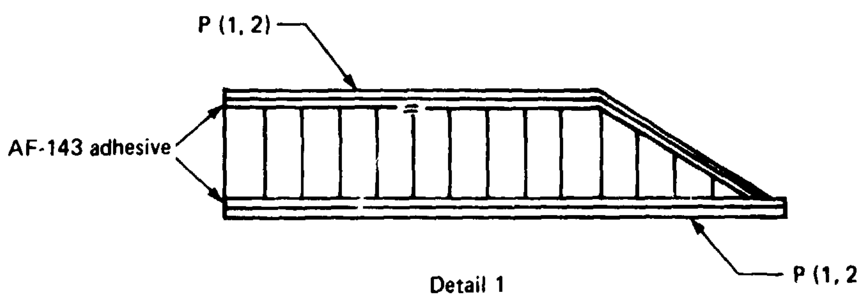


Figure 3-11. Skin Panel Standard





Ply No.	Orientation
1	0^o
2	0^o

Material:
BMS 8-212
Type II, Class 2
Style 3K-70-P

Core – Nomex, 0.32-cm (0.125-in) cells

1 — 1.27 x 1.27-cm (0.5 x 0.5-in) defect
2 — 2.54 x 2.54-cm (1 x 1-in) defect

Figure 3-12. Taper Edge Standard

- Upper and lower skin panels were fabricated per drawing 65C-17707-902 and 65C-17707-903 from station 136.50 to 173.21. The built-in defects, ranging from 0.64 x 0.64 cm (0.25 x 0.25 in) to 2.54 x 2.54 cm (1 x 1 in), were introduced throughout the panels, as shown in Figure 3-13.

- The two skin panels were sealed at the tapered end to make a trailing-edge assembly. The defect size ranged from 1.27 x 1.27 cm (0.5 x 0.5 in) to 5.08 x 5.08 cm (2 x 2 in). The details are shown in Figure 3-14.

- The rear spar standard, Figure 3-15, was built per drawing 65C-1707-7E, from station 117.0 to 99.79. The defects ranged from 0.64 x 0.64 cm (0.25 x 0.25 in) to 2.54 x 2.54 cm (1 x 1 in).

- The front spar standard, Figure 3-16, was built per drawing 65C-17707-9006E, from station 149.34 to 129.19, with defects ranging from 0.64 x 0.64 cm (0.25 x 0.25 in) to 2.54 x 2.54 cm (1 x 1 in).

- The rib standard, Figure 3-17, was built per drawing 65C-17707-4E, full size. The defects ranged from 0.64 x 0.64 cm (0.25 x 0.25 in) to 2.54 x 2.54 cm (1 x 1 in).

3.3.3 Fabrication Method

The NDI standards were fabricated per BAC 5562. The defects were introduced in the laminate panels, as outlined in Figure 3-7. In the production standards, however, the cutting out of fabric or tape was discontinued, and 2 shims of 2-mil Teflon were introduced in between the fabric or tape layers. In the honeycomb assemblies, the defects were introduced as outlined in Figure 3-18.

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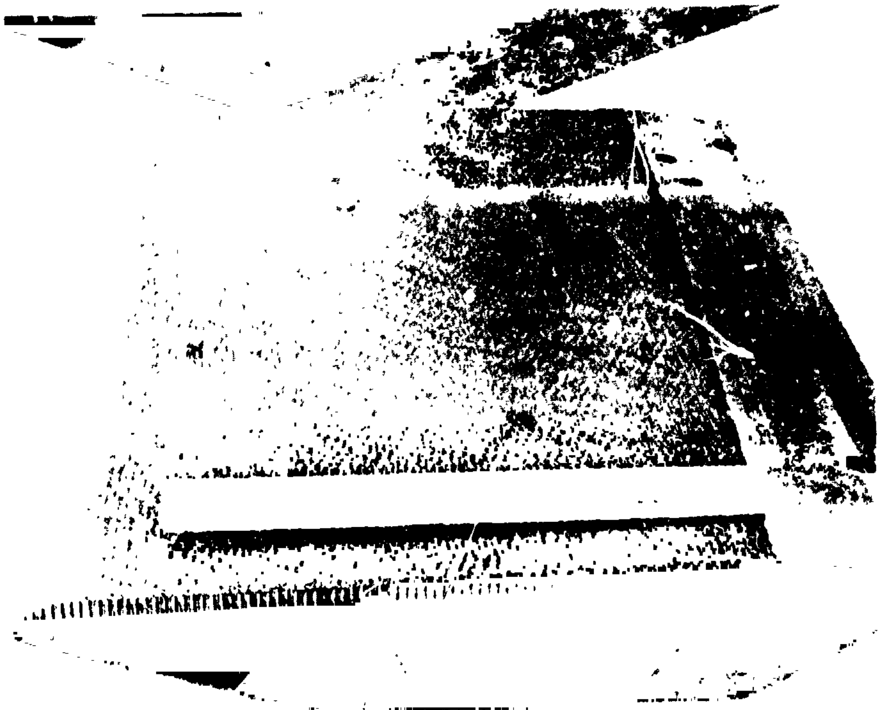

Figure 3-13. 727 Advanced Composites Elevator Skin Panel Standard

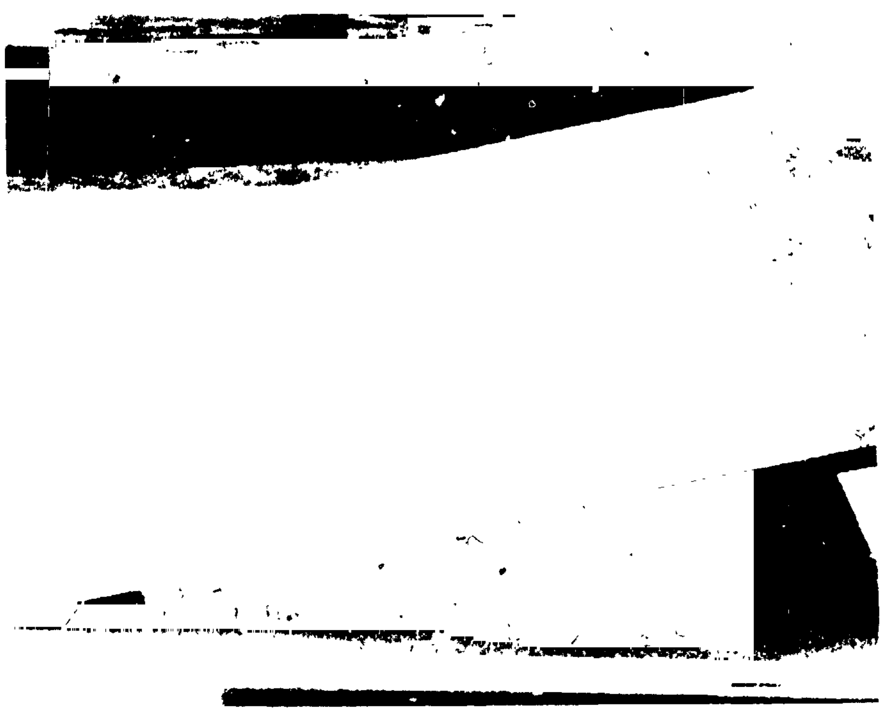

Figure 3-14. 727 Advanced Composites Elevator Trailing-Edge Assembly Standard

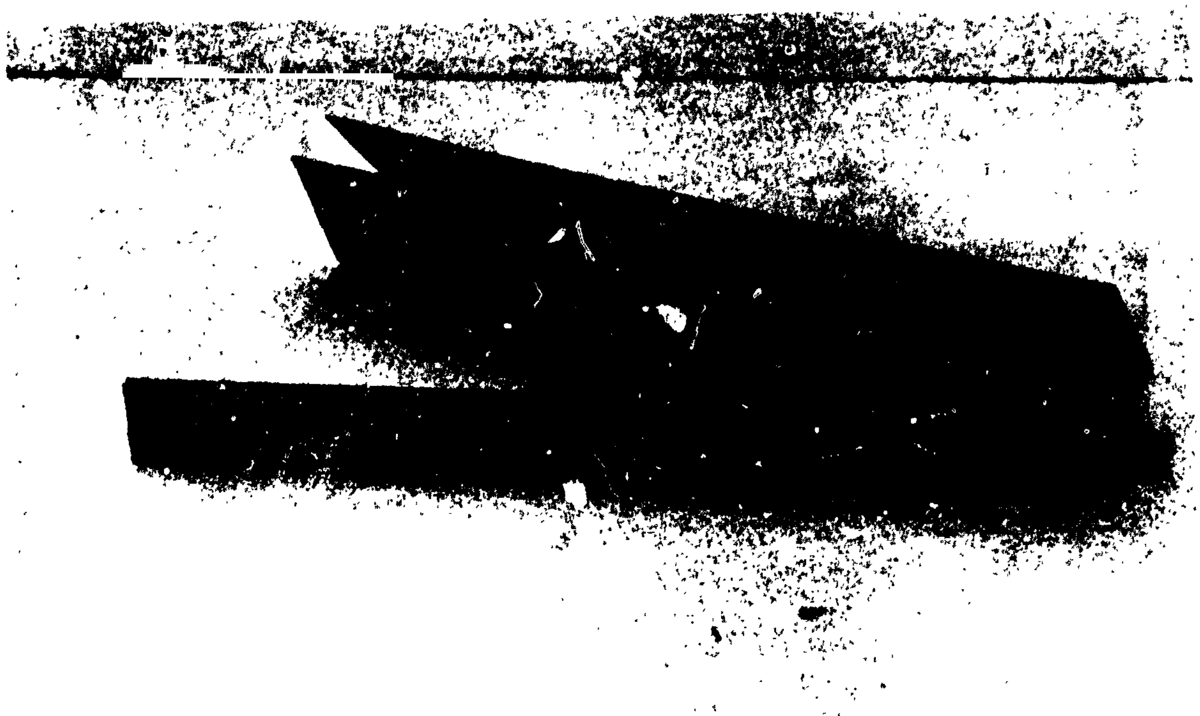

Figure 3-15. 727 Advanced Composites Elevator Rear Spar Standard

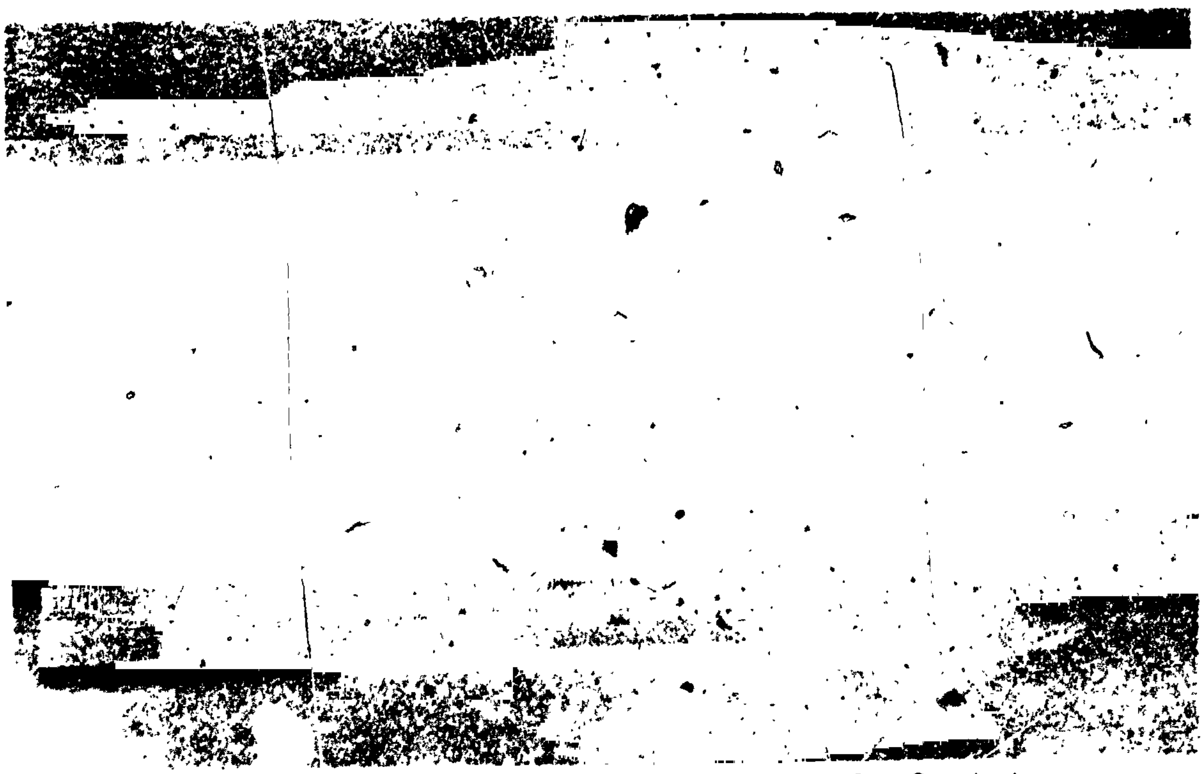

Figure 3-16. 727 Advanced Composites Elevator Front Spar Standard

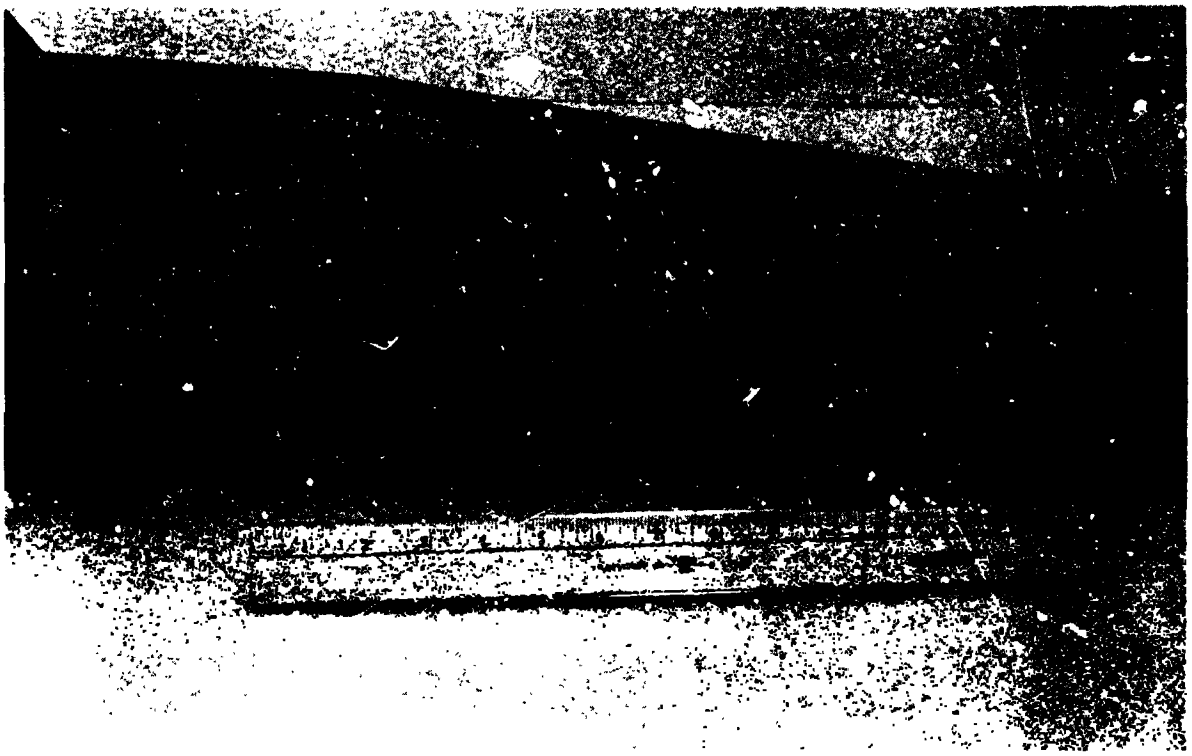

Figure 3-17. 727 Advanced Composites Elevator Rib Standard

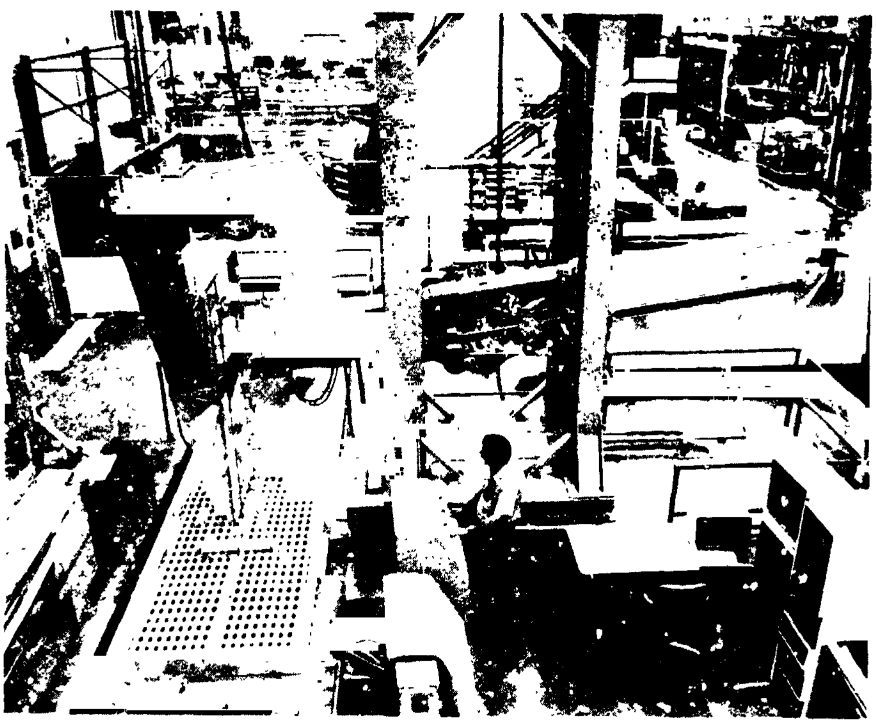

Figure 3-18. Automated TTU Scanner

3.3.4 NDI Techniques

NDI techniques evaluated during this investigation were the following:

- Through-transmission ultrasonic (TTU), with automated scanning and computerized C-Scan recording
- Through-transmission ultrasonic, with manual scanning and a visual signal display having C-Scan recording capability
- The Sondicator, Model S-1 or S-2B
- The Fokker Bond Tester
- Low kV X-ray (15-40 kV)

3.3.5 Test Results

All NDI standards were evaluated by the above-mentioned techniques. Through-transmission ultrasonic was the most sensitive method for production application. When a permanent record is not required, the portable instruments can be used. The automated through-transmission ultrasonic unit with computerized C-Scan recording capability is shown on Figure 3-18. Figure 3-19 shows a sample of computerized C-Scan recording. Voids, delaminations, or porosity indications are shown by darker recording (and higher numbers). A semiportable model of through-transmission ultrasonic without C-Scan capability is shown in Figure 3-20. Most of the production parts can be inspected by through-transmission ultrasonic, except some configuration, (Figure 3-21), are not suitabl for this inspection. Other examples of parts uninspectable by through-transmission ultrasonic are small corner radii, flanges of spars and ribs, and sealed area of trailing-edge assembly. These areas can be inspected by other techniques, as shown in Figures 3-22, 3-23, and 3-24.

Boeing Commercial
Airplane Company
Contract NAS1-14952

GRAPHITE TEST PANEL
PART NUMBER = 11423A
DATE = 3/ 9/78
SCANNER INDEX = 60 THOUSANDTHS
X SCALE = 1 Y SCALE = 1
PLOTTING SEQUENCE = 1,0,0,0,0,0.

SERIAL NUMBER = 000
CALIBRATION PROCEDURE = L4
SCAN PATTERN = A
SCAN DIRECTION = LEFT
NUMBER OF OPERATIONAL CHANNELS = 1

SIGNAL IDENTIFICATION LEVELS

LEVEL	MAX VOLTS*100
0	1000
1	700
2	335
3	285
4	255
5	225
6	190
7	155
8	115
9	75
10	50
11	30
12	15

PLOTTED SYMBOLS

1000	.GT.	BLANK	.GE.	700
700	.GT.	:	.GE.	335
335	.GT.	1	.GE.	285
285	.GT.	2	.GE.	255
255	.GT.	3	.GE.	225
225	.GT.	4	.GE.	190
190	.GT.	5	.GE.	155
155	.GT.	6	.GE.	115
115	.GT.	7	.GE.	75
75	.GT.	8	.GE.	50
50	.GT	9	.GE.	30
30	.GT.	10	.GE.	15
15	.GT.	11	.GE.	0

TOTAL NUMBER OF BLOCKS = 210

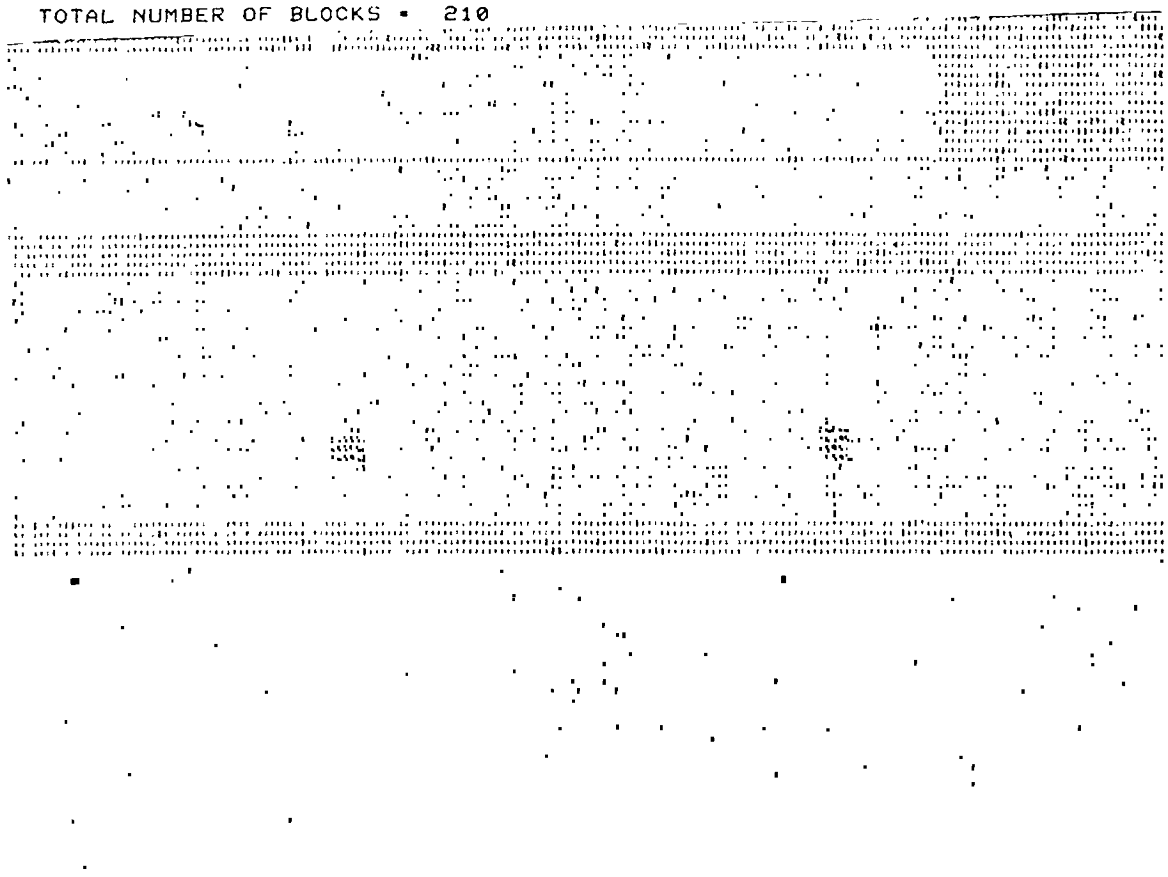

Figure 3-19. Graphite/Epoxy Test Panel Standard, Computerized C-Scan Recording

Figure 3-20. Semiportable TTU Scanner Without C-Scan Capability

Figure 3-21. Semiportable TTU Scanner, Showing Part Configuration Not Suitable for TTU Scan

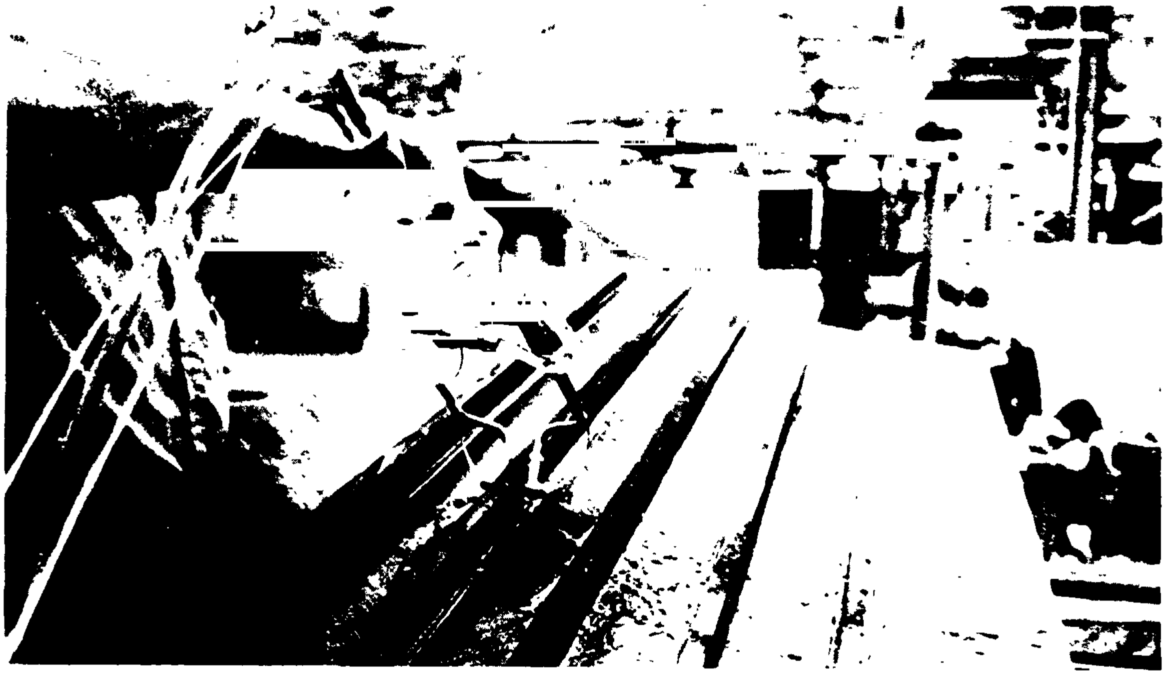

Figure 3-22. Portable TTU Scanner, Showing Inspection of Flange Area by Hand-Held TTU Unit

Figure 3-23. Sondicator Inspection of Configuration not Suitable for TTU Scan

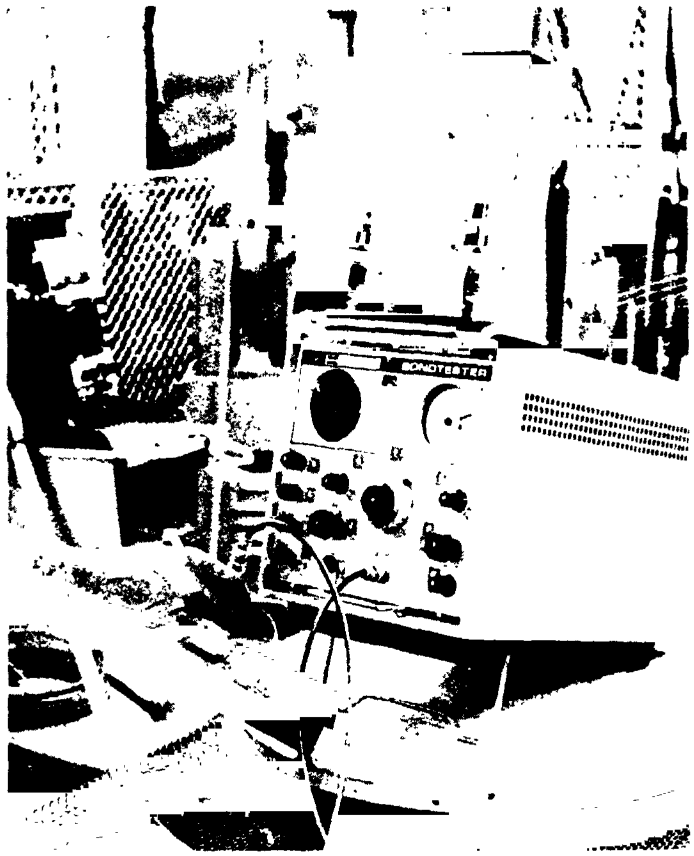

Figure 3-24. Fokker Bond Testing of Configuration not Suitable for TTU Scan

3.3.6 Conclusions

- All defects in the NDI standards are detectable by one or more of the NDI techniques

- Production parts can be inspected by using through-transmission ultrasonic to detect defects, 0.64 x 0.64 cm (0.25 x 0.25-in) or larger.

- Some part configurations, such as rear spar, flange areas of spars and ribs, small corner radii, and sealed area of trailing-edge assembly, cannot be inspected by through-transmission ultrasonic technique

- Rear spar, and flanges of spars and ribs, can be inspected by using hand-held through-transmission ultrasonic, the Sondicator, or the Fokker Bond Tester. Because of usual limitation of the manual scanning, the realistic defect detection capability is 1.27 x 1.27 cm. (0.5 x 0.5 in).

- The sealed area of the trailing-edge assembly can be inspected by the Sondicator or X-ray. The detection capability of the Sondicator is 1.27 x 1.27 cm (0.5 x 0.5 in), while X-ray technique can detect minute voids in the sealant.

- In-service and maintenance inspection can be accomplished by the Sondicator, the Fokker Bond Tester, and/or X-ray (when practical). Since these inspection conditions are not as favorable as the laboratory or production environment, the realistic defect detection capability for the Sondicator and the Fokker Bond Tester is expected to be 2.54 x 2.54 cm (1 x 1 in) or larger.

3.4 VERIFICATION HARDWARE

Details and assembly of the 203-cm (80-in) long, full-scale section of the verification hardware have been completed (Figures 3-32 and 3-33). The structure verified the production detail tools, and assured Manufacturing that no major assembly problems will be encountered during production of the 5-1/2 shipsets.

The verification hardware was also used as a training aid for production assembly personnel. Two significant facts were learned from the verification hardware:

1. It was concluded that using only a section of the structure to verify the fabrication and assembly processes will not always identify all of the problems associated with the full-size structure.

The 203-cm (80-in) front spar and short rear spar used for the verification hardware showed only slight warpage after fabrication. However, the full-size production spars showed excessive warpage, causing rejection of the front spar and scrapping of the rear spar. Based on this experience, full-size detail parts should be fabricated.

2. During fabrication of the concept verification hardware (test hardware), dimensional problems occurred with the ribs. It was concluded that these problems occurred because all ribs were fabricated on male tools that were made by scaling the photo contact master (PCM) drawing. Variations in the PCM drawing and the scaling process accounted for the dimensional discrepencies.

The verification ribs were fabricated on production male tools, which were made using master dimensioning index (MDI) data, and numerical control machining. No dimensional descrepencies were found in ribs fabricated from these tools.

Figures 3-25 through 3-33 show the verification hardware (Test No. 16), during fabrication and assembly.

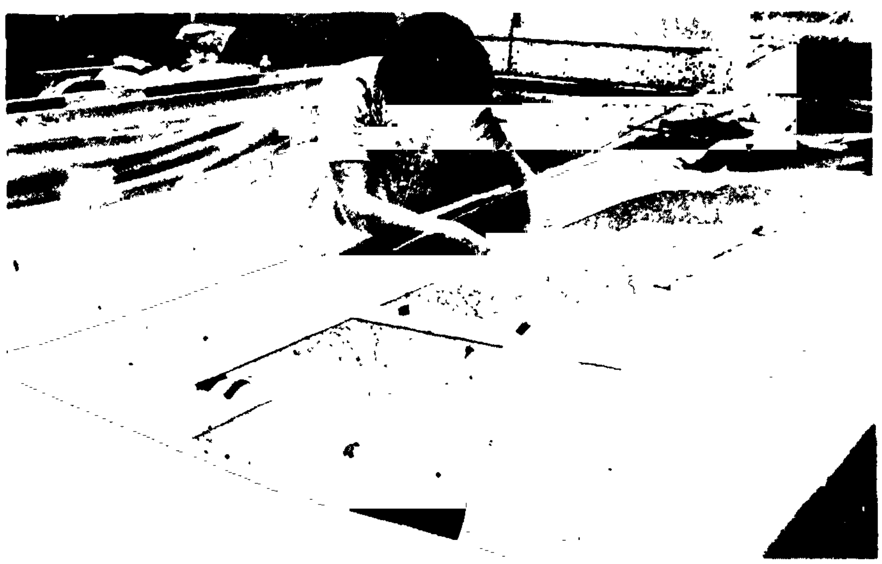

Figure 3-25. Manufacturing Verification Hardware, Test No. 16 Skin Panel, Showing Doubler Being Laid Up

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Figure 3-26. Manufacturing Verification Hardware, Test No. 16, Showing Completed Skin Panel

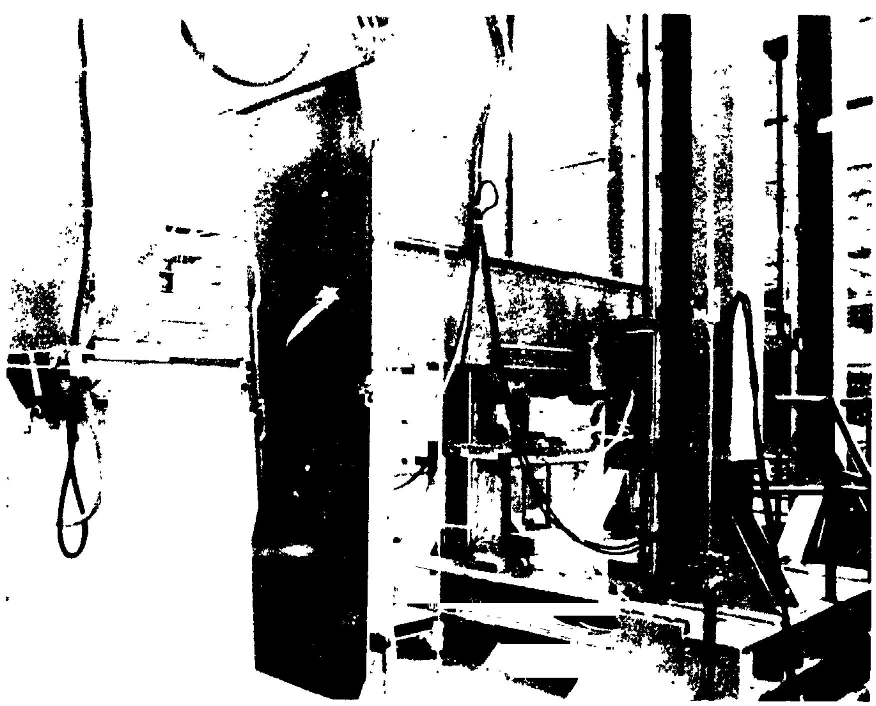

Figure 3-27. Manufacturing Verification Hardware, Test No. 16, Showing Skin Panel in TTU Inspection

Figure 3-28. Manufacturing Verification Hardware, Test No. 16, Showing Front Spar Being Laid Up

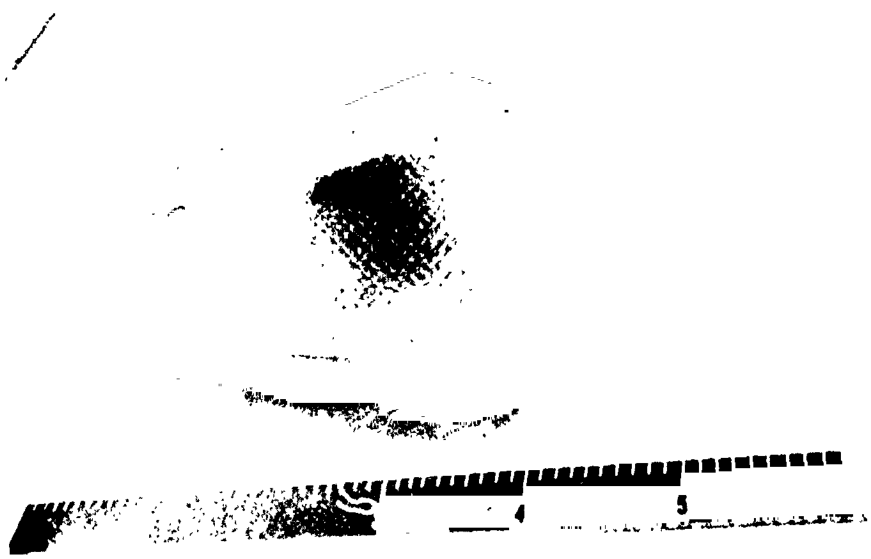

Figure 3-29. Manufacturing Verification Hardware, Test No. 16, Showing Completed Rear Spar Header

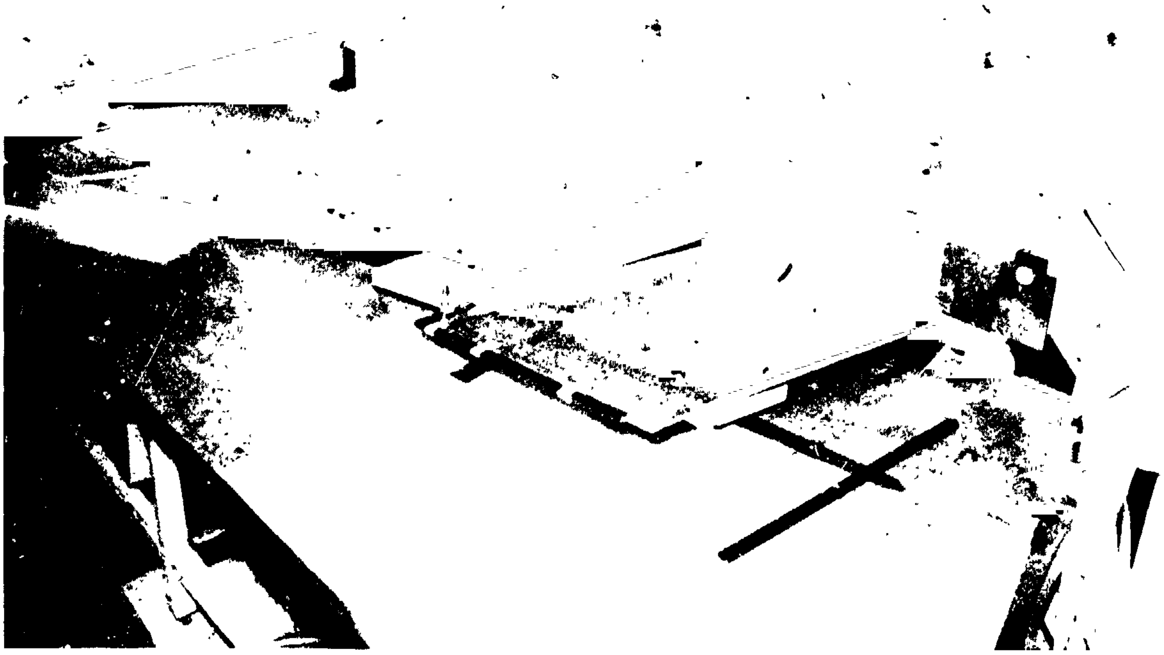

Figure 3-30. Manufacturing Verification Hardware, Test No. 16, Showing Front Spar, Two Ribs, and Lower Skin Being Assembled

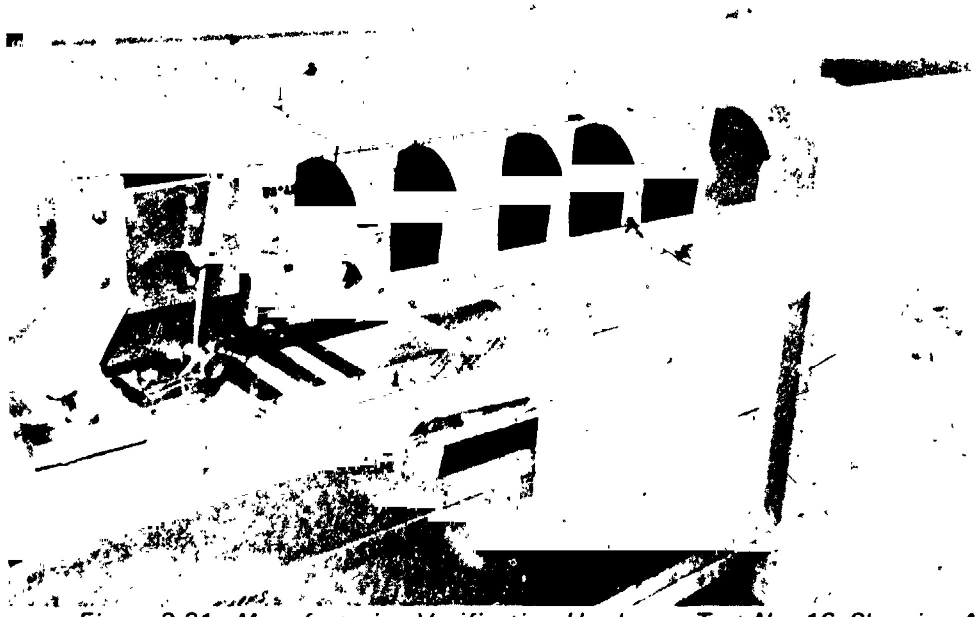

Figure 3-31. Manufacturing Verification Hardware, Test No. 16, Showing Aluminum Nose Ribs Being Attached to Front Spar

Figure 3-32. Manufacturing Verification Hardware, Test No. 16, Showing Front View of Completed Assembly

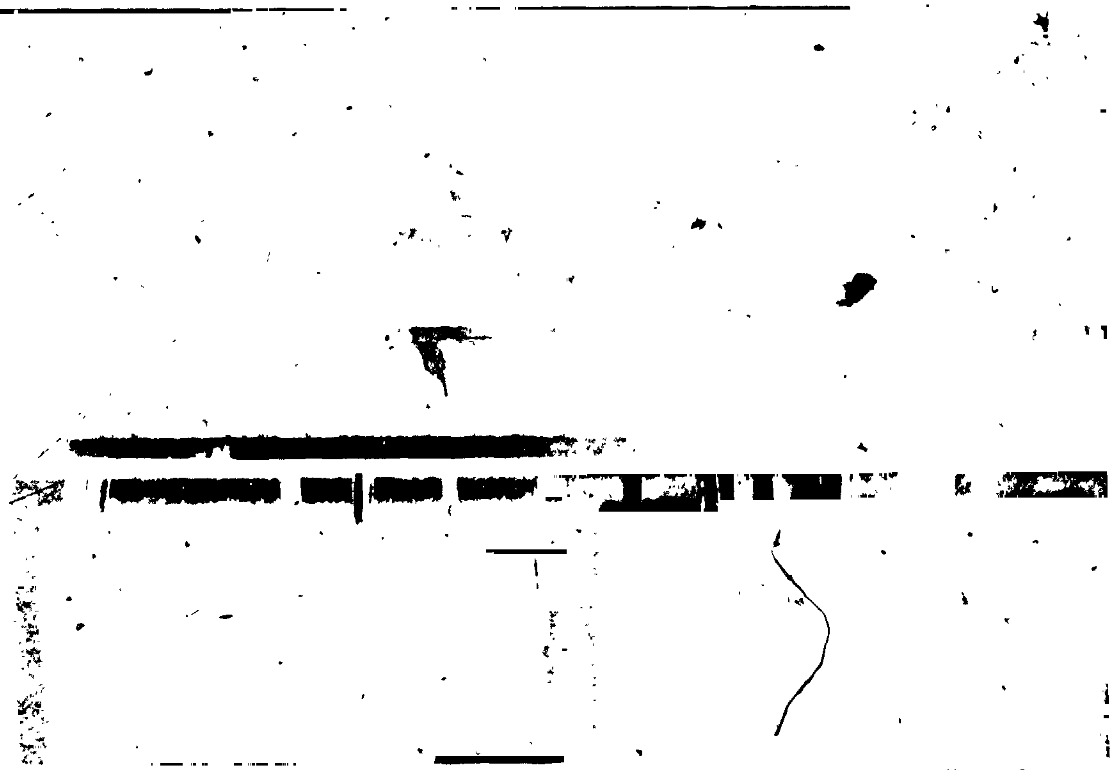

Figure 3-33. Manufacturing Verification Hardware, Test No. 16, Showing Rear View of Completed Assembly

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SECTION 4.0

PRODUCTION

This section discusses the production status of the program.

4.1 ASSEMBLY TOOLS

Fabrication of left-hand assembly tooling is proceeding per schedule. The front spar final assembly jig is in the final steps of tool tryout (Figure 4-1). The rear spar final assembly jig was completed during the report period, and is presently set up in the assembly shop, where tool tryout is being accomplished (Figure 4-2). The major assembly final assembly jig is also complete, and being set up in the assembly shop (Figure 4-3). Assembly work and tool tryout will activate in the major position during the next reporting period. Remaining activity under this work breakdown structure involves completion of rework to the existing elevator tab tool to provide dual usage, and fabrication of the transportation/storage dolly for the left-hand unit.

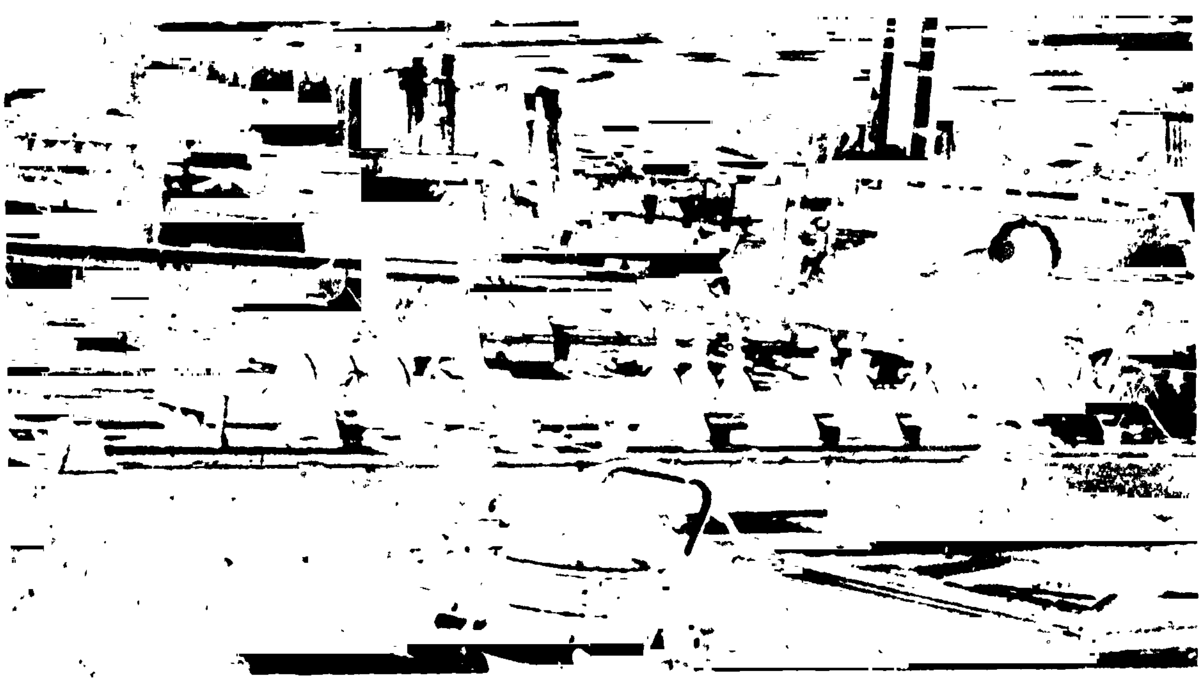

Figure 4-1. Front Spar with Nose Ribs Installed and Located in Tool

Figure 4-2. Final Assembly Jig for Left-Hand Rear Spar

Figure 4-3. Major Assembly Jig Being Set Up in Shop

4.2 COMPONENT MANUFACTURE

Fabrication division has completed production of all advanced composites components for the left-hand test unit, except for the skin panels and tabs. These components were scheduled for completion during August. Significant problem areas encountered during the fabrication of advanced composites production parts, and the changes instituted to correct them, are as follows:

Problem No. 1:	Difficulty in maintaining proper fitup of 65C17546-5 and -13 rear spar headers to the 65C17546-3 spar, due to corner thicknesses.
Fix:	Layup of the rear spar headers was changed so that only the inner and outer plies of fabric will be overlapped in the four corners. The middle five plies will be butt-spliced at the corners. This change will eliminate the thick corners that caused the improper fitup conditions (Figures 4-4 and 4-5).
Problem No. 2:	Fabrication of skin panels encountered difficulties with engineering requirements for overlapping splice doublers and filler plies.
Fix:	Fabrication division was given authority to overlap the splice doublers only, and to butt-splice all filler plies per BAC 5562. This method adapts to a production environment, produces higher quality skins, and has a higher material utilization.

Activities associated with assembly of the left-hand test elevator, which began July 10, 1978, are as follows:

Figure 4-4. Rear Spar with -5 Rear Spar Header Installed, Showing Mismatch

Figure 4-5. Rear Spar Header, Showing Bow in Side

1. <u>65C17529-950 Rib Assembly</u>

This is the backup rib that attaches to the main actuator fitting. All components are of advanced composites material. It is now complete and in storage. No difficulties were experienced in fitup of parts or drilling operations (Figures 4-6 and 4-7).

2. <u>65C17546-950 Rear Spar Assembly</u>

No assembly work has been accomplished as yet. Assembly parts are being utilized for tool tryout. Relative to the close-down of the channel-shaped rear spar in its cured condition, there appears to be no problem with springing the channel sides open far enough to install the headers and tab hinge fittings.

3. <u>65C17545-950 Front Spar/Leading-Edge Assembly</u>

Assembly work is proceeding, along with tool tryout work. Nose rib attach angles have been installed, and the spar halves have been attached to the main actuator fitting. Nose rib assemblies have been prefitted to the attach angles, and fastener locations have been drilled.

Relative to the warp in the spars that occurs during the cure cycle, it is noted that installation of the nose rib attach angles corrects the condition.

Utilizing the special drills and 18,000 r/min motors for drilling of fastener holes through the advanced composites parts did not present any problems where tooling provisions included a positve guide. Drilling free-hand caused some concern, due to the ability of the special drills to act like a router and cause oversize holes. Free-hand drilling techniques were covered during training class to help control this problem. A number of holes must be free-hand drilled.

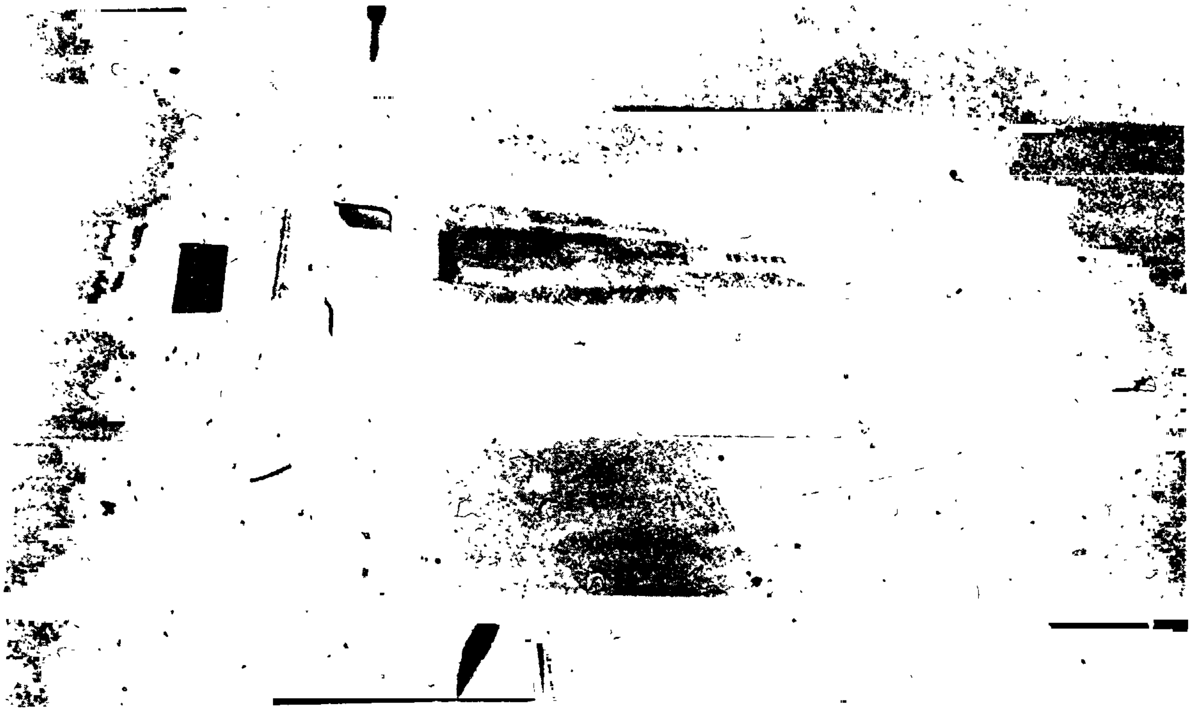

Figure 4-6. Detail Parts of 65C17529-950 Rib Assembly

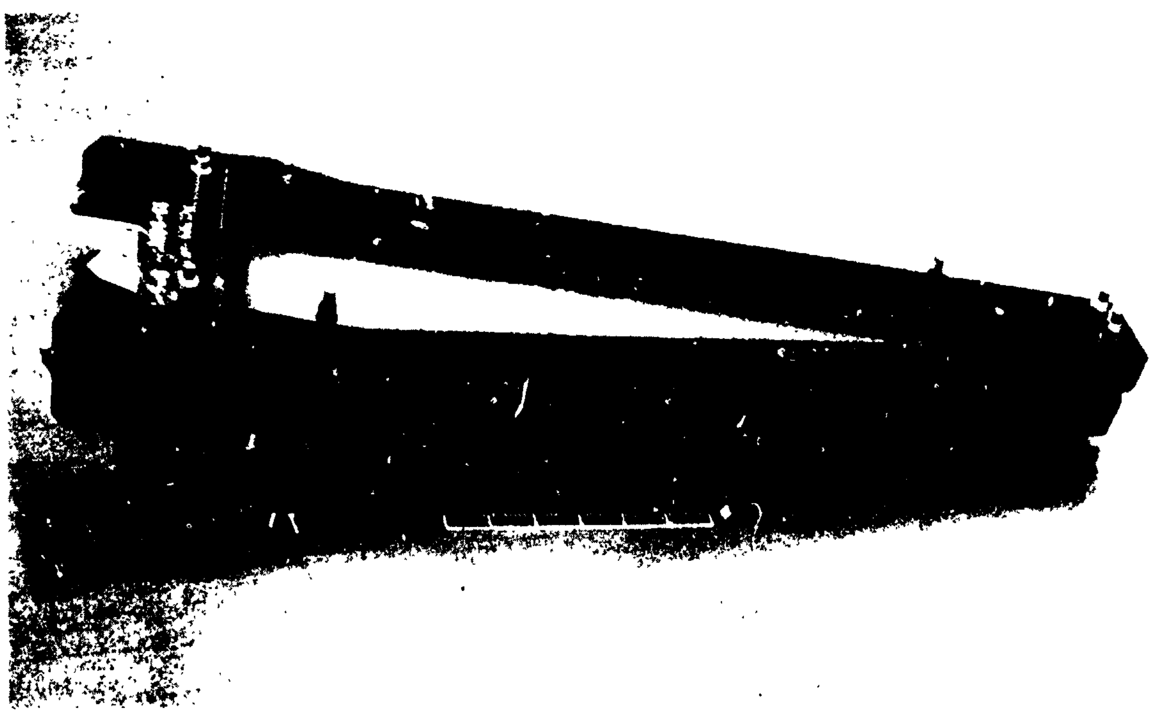

Figure 4-7. Completed 65C17529-950 Rib Assembly

Modification to vacuum dust collection features developed for the drill motors has been required to correct interference problems (Figures 4-8 and 4-9). MR&D is working on further refinements to improve efficiency.

Breakout of graphite/epoxy fiber has not been experienced. There is breakout in the fiberglass first ply, but this is not a problem. The fiberglass ply is a corrosion barrier only (Figure 4-10).

In most cases, the grip length callout for fasteners is too short, because graphite/epoxy parts are on the high side of the thickness tolerance range. All drawings have now been reexamined by Engineering, and revised EAMRs calling out longer grip lengths, where required, have been issued. The 707/727/737 Materiel department, working from advanced information and the revised EAMRs, is in the process of determining supply sources and expediting shipments of new grip length fasteners. It is noted that the majority of fasteners are unique to the elevator program, are not shelf-stock items at Boeing or the suppliers, and require extended lead times for procurement. The Manufacturing department is working with Engineering to determine where available substitute fasteners can be used. Production schedule impact will be assessed, when all aspects of fastener availability have been examined.

Assembly progress has been paced by tool tryout. The major assembly load date of August 17, 1978, will be met. Fastener availability would be the only constraint.

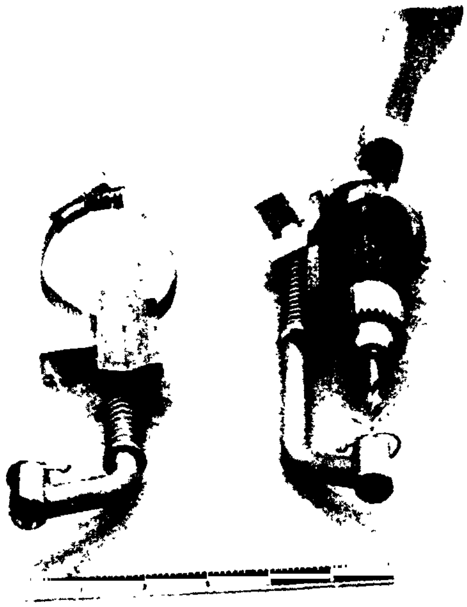

Figure 4-8. Hand Drill (right), Showing Standard Vacuum Unit and Modified Vacuum Unit (left)

Figure 4-9. Drilling Attach Angles on Front Spar, Showing Interference Between Angle and Vacuum Collar

Figure 4-10. Nose Rib and Attach Angle, Showing Fiber Breakout of Fiberglass First Ply

SECTION 5.0

REFERENCES

1. "727 Structural Design Loads," Boeing Document D6-5863.

2. "727 Horizontal Tail Stress Analysis," Boeing Document D6-5873.

3. "Boeing Design Standards," Boeing Document D-5000.

4. "Advanced Composites Design Guide," Volumes I through IV, Third Edition.

5. "Requirements for Epoxy Resin Impregnated Graphite Fibers," Boeing Document BMS 8-212.

6. "Manufacture of Autoclave Cured Graphite/Epoxy Structural Parts," Boeing Document BAC 5562.